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U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN NO. 172 (Revised).

A. C. TRUE, Director.

IRRIGATION IN MONTANA.

BY

SAMUEL FORTIER,

ASSISTED BY

A. P. STOVER AND J. S. BAKER.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1906.

LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON IRRIGATION AND DRAINAGE.

NOTE.—Publications marked with an asterisk (*) are not available for distribution.

*Bul. 36. Notes on Irrigation in Connecticut and New Jersey. By C. S. Phelps and E. B. Voorhees. Pp. 64.

*Bul. 58. Water Rights on the Missouri River and its Tributaries. By Elwood Mead. Pp. 80.

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Bul. 130. Egyptian Irrigation. By Clarence T. Johnston. Pp. 100.

Bul. 131. Plans of Structures in use on Irrigation Canals in the United States, from drawings exhibited by the Office of Experiment Stations at Paris, in 1900, and at Buffalo, in 1901, prepared under the direction of Elwood Mead, chief. Pp. 51.

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THE OFFICE OF EXPERIMENT STATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., October 20, 1906.

Sir: I have the honor to transmit herewith a revised report on Irrigation in Montana, prepared by Samuel Fortier, assisted by A. P. Stover and J. S. Baker, under the direction of Elwood Mead, Chief of Irrigation and Drainage Investigations, and to recommend that it be published as a bulletin of this Office for circulation primarily in Montana, although its suggestions should be of value to the arid region generally.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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IRRIGATION IN MONTANA.

In the early stages of agricultural development in Montana, as in the other arid States, the economical use of water was not important. The supply was large in proportion to the demand, and securing capital to build irrigation works, and methods of building ditches, preparing land, and applying water were the important matters. But those conditions are passing, and the State is entering upon the stage in which continued agricultural development will depend upon the economical use of its water supplies. This report is based upon a study, made for the purpose of determining whether the existing methods and institutions will lead to the best use of water. The work included the study of irrigation practice in Gallatin and the Yellowstone valleys; seepage losses from ditches and methods of prevention throughout the the State; volume of return seepage to streams in the Bitter Root Valley; and water-right records in the Gallatin Valley. It is believed that this study of typical localities gives a fair understanding of conditions throughout the State.

LAND AREAS.

On June 30, 1903, there were over 18,000,000 acres of Government land in the State open for settlement under the various laws. On the same date there was nearly 40,000,000 acres unsurveyed. These two items comprise nearly 65 per cent of the total land area. The area included in the forest reserves is about 7,500,000 acres, and the six Indian reservations prior to the opening of a part of the Crow Reservation aggregated about 9,500,000 acres. In addition, there is the area appropriated, which has increased of late years by more than a million acres a year. In 1899 it was 13,000,000 and in 1905 it was 19,279,000 acres. A more exact statement, taken from the Report of the Commissioner of the General Land Office regarding the status of land in Montana on July 1, 1905, is herewith given:

	Acres.
Area surveyed and open for settlement	19,241,264
Area unsurveyed	36,507,106
Area reserved	18,566,188
Area appropriated	19,279,012

A considerable portion of the area appropriated has been purchased from the Northern Pacific Railroad Company. The grant to this company comprised about 15,000,000 acres, of which nearly one-half has been patented and sold to private parties. According to the Congressional Record of March 25, 1904, the public lands of Montana disposed of from July 1, 1881, to June 30, 1902, are as follows:

	Acres.
Timber and stone lands	171,977
Final desert entries	1,284,431
Commuted homesteads	383,121
Final homesteads	1,573,777
State lands selected	961,621
Railroad grants patented	6,611,083
Total in twenty-one years	10,986,010

Only about 10 per cent of the land that has been appropriated is farmed, and of this portion about two-thirds is irrigated. The total area irrigated in 1904 was probably 1,250,000 to 1,500,000 acres. It is from this comparatively small area that the greater part of the agricultural wealth, exclusive of stock interests, is derived, and from which a large part of the total revenues are raised. In 1902 the State board of equalization assessed 10,542,536 acres at $25,300,972, or $2.40 per acre. This average rate is low for the reason that unfenced grazing lands were assessed at only 75 cents and railroad lands at 85 cents per acre. On the other hand, first-class grain lands under irrigation were occasionally assessed as high as $30 per acre. On an average, 1 acre of grain land is assessed as high as 10 acres of grazing land.

According to the census of 1902, 1,140,694 acres were irrigated in Montana. This was an increase of 18.1 per cent over the area irrigated in 1899. More land has been reclaimed during the two years that have followed than in the two that preceded that date, so that it is safe to assert that there are over 1,500,000 acres under irrigation.

THE WATER SUPPLY.

For an arid State, Montana is well watered. Occupying the crest of the continent, many rivers have their sources in its elevated ranges and mesas. Some of these streams have not as yet been utilized to any great extent for irrigation, and in consequence their water has little present value. Others are partially utilized, while still others have been wholly appropriated. However, only a few of the larger streams have ever been measured and little is known of the discharge of scores of the smaller rivers and creeks. The following summary of the annual discharge of some of the principal rivers in 1903, as determined by the engineers of the United States Geological Survey, may convey some idea of the extent of the water supply.

Discharge of Montana rivers, 1903.

	Acre-feet.
Yellowstone River at Livingston	2,654,000
Gallatin River at Logan	841,000
Madison River at Morris	1,265,000
Jefferson River at Sappington	1,872,000
Bitter Root River at Grantsdale	1,128,000
Missoula River at Missoula	2,459,000
Big Blackfoot River at Bonner	1,026,000
Marias River at Shelby	1,183,000
St. Mary River at International Line	1,213,000
Total[a]	13,641,000

The water supply for 1903 was about normal. On account, however, of the short irrigation season the full flow of streams can not be utilized without storage for more than a third of the year. It is true this growing period occurs at a time when the rivers are high, but even with this favorable condition it is not possible to utilize for irrigation purposes more than one-half of the total yearly flow. The data regarding the quantities of water which can be retained in the smaller streams are too limited and uncertain to enable one to estimate with any degree of accuracy the number of acres which can be irrigated from these sources. From a more or less intimate knowledge of the water resources of the State, the writer would place the limit at 6,000,000 acres as being the largest amount of land which can be irrigated in Montana from all sources, including stream flow, storage reservoirs, and wells.

It may be stated in a general way that for every acre that can be irrigated there will be nearly 2 acres that may be cultivated dry and 10 acres that will afford pasture for stock. How to make the best possible use of 6,000,000 acres of irrigable lands, of 10,000,000 acres of arable bench lands, and of 50,000,000 acres of grazing lands is the most vital and far-reaching question that is likely to arise in Montana for the next quarter of a century. It has always seemed to the writer that the ideal farm in this mountain State would consist of 40 acres of irrigated land with a good water right, about 40 to 80 acres of arable bench land, and about 640 acres of fenced grazing land on a near-by mountain slope.

CLIMATE.

The climate of Montana is arid and is typical of much of the Rocky Mountain region, but nearly 70 per cent of the average precipitation of 14.5 inches occurs during the crop-growing season. Few records have been taken to show the heavy precipitation on the mountain slopes. The officers of Fort Yellowstone, in the Yellowstone National Park, claim that the depth of snow varies from 10 feet in the neighborhood of Mammoth Hot Springs to 20 feet at the higher elevations within and adjacent to the park. The light snowfall in the valleys during the winter months is usually speedily evaporated by the chinook winds, which are met with from Oregon to Nebraska and from the Peace River to Arizona, and are particularly common in Montana, doing much to modify the climate.

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[a] The Missouri River is not included for the reason that the greater part of its discharge is derived from the Gallatin, Madison, and Jefferson rivers.

While the temperature often reaches −40° F. at Havre, which lies in the direct path of the winter storms from the north and northwest, the lowest record at Missoula for twenty-three years is −22° F., and in some winters the mercury does not go below the zero point. In many parts of the State the spring months are the most disagreeable. March, April, and May are the worst, and the sunshine of June is often obscured by showers of soft snow. But with two hundred and seventy-three sunshiny days and only ninety-two rainy days in the year, the Montana farmer receives with gratitude his allotment of June snow, because it benefits his crops and may save him the work of a second irrigation.

CROPS.

In response to a large number of circular letters which were sent out in the summer of 1904 from the Montana Experiment Station, the yields and value of the ordinary crops grown in the principal irrigated valleys of the State were obtained. The accompanying statement represents the averages of all the complete replies received to an inquiry sent to representative farmers regarding the principal crops in their neighborhood, the average yields per acre, and the prevailing prices for the past few years:

Crop returns in Montana.

Kind of crop.	Yield per acre.	Price.	Value.
Wheat	33 bushels	$1 per cwt	$20.16
Oats	57.90 bushels	$1.04 per cwt	19.27
Barley	56.50 bushels	$1.03 per cwt	25.24
Alfalfa	4.18 tons	$5.19 per ton	21.69
Timothy	1.46 tons	$9.43 per ton	13.77
Clover	3.67 tons	$5 per ton	18.35
Potatoes	200 bushels	50 cents per cwt	60.00
Deciduous fruits and berries			100.00

The yields with their corresponding values given in the table are considerably above the average of the irrigated portion of the State. In many parts both water and land are cheap, and careless methods of farming are practiced. The land is not properly cultivated and much of the water applied does more harm than good. Farmers seem to prefer to go to the expense and trouble of cultivating 100 acres in a slipshod manner for half a crop rather than to farm 50 acres in a skillful way for a full crop. The figures of crop yields, however, represent with a fair degree of accuracy what can be accomplished when care and skill are exercised in cultivating the soil and applying the water.

Nearly three-fourths of all the wheat and rye grown in the State are produced on dry farms. A large part of the oats and barley is also raised on dry farms, so that more than one-half of the entire cereal crop comes from the unirrigated farms. This branch of farming is increasing at a rapid rate. Plowed fields, which at one time were confined to the lowlands, are now found far up the mountain side, and it is safe to assert that in a very few years several million acres will be cultivated in this manner.

In developing this feature of its agricultural wealth Montana is imitating the course pursued by California. The valley lands of the San Joaquin and Sacramento valleys have been producing grain for forty years without being irrigated. The soil in these valleys is of great depth and at one time gave heavy yields, but the continuous cropping of grain without rotation has reduced the yield until now many farmers consider themselves fortunate when the returns at the close of the season's operations show no loss. The bench lands of Montana are likely to fail to produce profitable yields at an earlier period, for the reason that the soil is less deep. Some kind of a simple rotation with a leguminous crop should be introduced, if possible. The rains in the spring are quite abundant as a rule, and if these should fail or prove inadequate, sufficient water can usually be had from the neighboring creeks to thoroughly wet the soil during the early spring or late autumn months.

With sufficient moisture and a thoroughly prepared seed bed, it is believed that alfalfa can be successfully raised over much of the arable but nonirrigable lands. The yield would be, as a matter of course, much less than on properly irrigated land; one medium crop, and under favorable conditions two, would be the average yield; but the yield is of secondary importance. By a simple rotation of this kind the productive power of the soil could be maintained and the dry farms made to yield for an indefinite period.

THE GALLATIN VALLEY.

Gallatin County, comprising a total area of 1,663,000 acres, is an irregularly shaped tract of land occupying the south-central part of the State of Montana. The southern portion of the county is mountainous and extends to the boundary of Idaho and the Yellowstone National Park; the land to the north is less elevated and affords fairly good range, while the middle portion of the county contains the rich alluvial plain known as Gallatin Valley. This valley is 28 miles long and about 14 miles wide. Around the upper rim the fall varies from 50 to 80 feet per mile, while from the Missouri River to Bozeman the average grade on the Northern Pacific Railroad is somewhat more than 30 feet per mile. The elevation of the railroad track at Bozeman, near the upper end of the valley, is 4,754 feet and at Logan, a small town located near the lower end of the valley and distant 24 miles, it is 4,032 feet. There is consequently a difference of 722 feet in elevation in 24 miles.

Gallatin Valley is for the most part surrounded by mountain ranges. To the south are to be found the sharp-pointed, snow-covered peaks of the Gallatin Mountains; on the east the steep incline from the East Gallatin River terminates in the Bridger Range, while a low range separates it from the valley of the upper Missouri River on the northwest and a plateau forms the divide between it and the Madison Valley on the west.

The people of Gallatin County paid taxes in 1902 on over half a million acres. This area was divided as follows:

Private land in Gallatin County, 1902.

	Acres.
First-class grain and hay land, most of which was irrigated	98,115
Second-class grain and hay land	112,910
Fenced grazing lands	205,130
Unfenced grazing lands	73,160
Railroad lands	58,831
Total	548,146

There were about 100,000 acres irrigated and about 110,000 acres cultivated dry in 1903. On an average 1 acre of irrigated land is as profitable as 3 or 4 acres of the same quality of nonirrigated land, for the reason that the former, under a proper rotation, will produce a crop every year while the latter has to be rested alternate years, the irrigated land producing also a greater diversity of crops.

In a general way the soils of the Gallatin Valley may be classed under two heads, viz, those derived directly from the disintegration of the materials of the Bozeman Lake beds and remaining in place and those formed by the sorting over of the above materials by the various streams of the valley. The first of these two classes constitutes the higher "bench" lands, while the other comprises the bottom lands bordering the streams or occupying the lower levels of the valley. These have much in common, yet there are also marked differences. Gravel is rarely found in the bench-land soil, while it is common in the bottom lands.

The thickness of the soil varies very greatly, averaging perhaps 12 inches, the subsoil averaging 2 feet, with usually gravel below. This is more particularly true of the bottom-land class. The soils are deeper and richer in humus in the upper end of the valley, whereas about the middle of the valley the gravel forms an extensive bar, reaching practically to the surface.

The following average of soils from the experiment station farm is typical of the better class of soils:

Average of soil of experiment farm.

	Per cent.
Coarse material	1.664
Fine earth	98.336
Analysis of fine earth:	
Insoluble matter	80.410
Soluble matter	19.590
Soluble silica	.130
Potash	.600
Soda	.360
Lime	1.160
Magnesia	1.150
Manganese oxid	.960
Peroxid of iron	3.920
Alumina	6.150
Phosphoric acid	.290
Sulphuric acid	.113
Organic matter	5.440
Moisture	4.080
Nitrogen	.170

The soils in general are loams with just the desirable proportion of sand to clay, so that on the one hand they are not too loose, while on the other they do not bake or offer obstacles to the free movement of crops.

Alkali is found in harmful quantity in only a few sections of limited extent.

CLIMATE.

The climatological records of the Montana Agricultural College cover only a few years, but this deficiency has been made up, in a large measure, by the painstaking labors of Mr. Peter Koch, of Bozeman, Mont. Mr. Koch began taking observations January 1, 1880, and continued them through a period of twenty years. Under the direction of the author a complete transcript of his records has been made into a permanent record book, to which have been added, from the college records, the data pertaining to the years from 1900 to 1902, inclusive. In the following paragraphs the results of Mr. Koch's records for twenty years, together with those of the additional years, are summarized.

From 1880 to 1902 the average rainfall at Bozeman has been a trifle more than 19 inches. Some portions of the cultivated area of Gallatin Valley have a greater precipitation, while other portions have less, the average for the entire valley being probably somewhat less than that of Bozeman. This precipitation is considerably more than that of the State as a whole. In this period there were a few dry years, notably 1889 and 1900, in both of which the precipitation fell below 15 inches.

This was chiefly due to the light snowfall, which in 1889 was only 1.5 inches in January, February, and March, and in 1900 3.24 inches during five of the winter months. The years of heavy precipitation were 1880 and 1892. In 1880 9.5 inches fell during the winter months of January, February, March, November, and December, and in 1892 8.5 inches in the same time. The yearly fluctuation of the fall of rain and snow from 1880 to 1901 is shown by figure 1.

In the monthly distribution of the precipitation, Gallatin Valley, and in fact the entire State, is highly favored. The greatest precipitation occurs during the months following seedtime (fig. 2). April, May, and June are the wettest months of the year. For the past twenty-two years the average precipitation for these months has been 1.99, 2.40, and 2.94 inches, respectively, or 7¼ inches in all. This quantity of moisture, which falls either as rain or soft snow, is nearly all absorbed by the properly tilled soil and supplies moisture not only to bring the plant well above the surface but to bring it well along toward maturity. August is the driest month, averaging 0.67 inch. The average for July is 1.1 inches. This midsummer period of dry, sunshiny weather enables the farmer to harvest his crops in good condition and at the least expense.

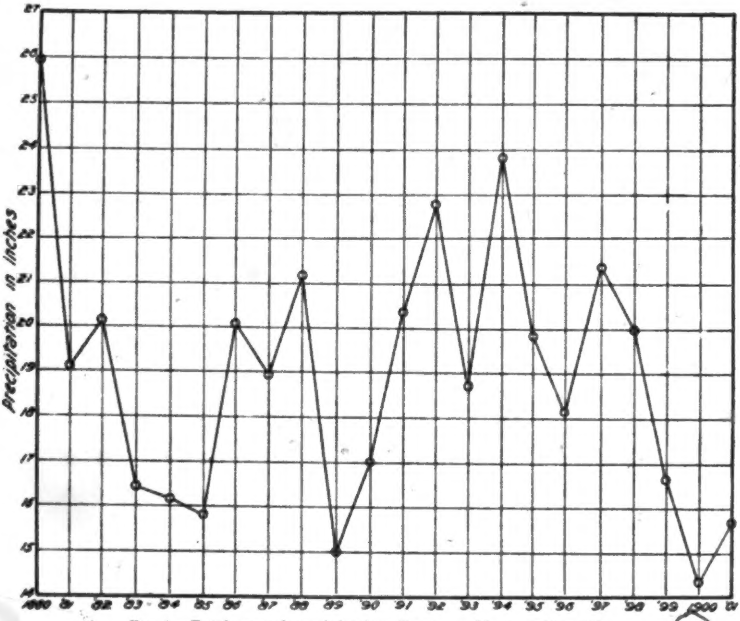

FIG. 1.—Total annual precipitation, Bozeman, Mont., 1880 to 1901.

The highest temperature at Bozeman during the past twenty-two years, as shown by Koch's records, is 100° F. The mean relative humidity of the Gallatin Valley is about 40 per cent. Only twice in twenty-two years has the mercury in the shade risen to 100° F. The average maximum temperature for that period is 93° F. Figure 3 shows the mean monthly temperatures from January 1, 1880, to January 1, 1902. The averages for June, July, August, and September are 57.1°, 63.8°, 65.7°, and 53.7°, respectively.

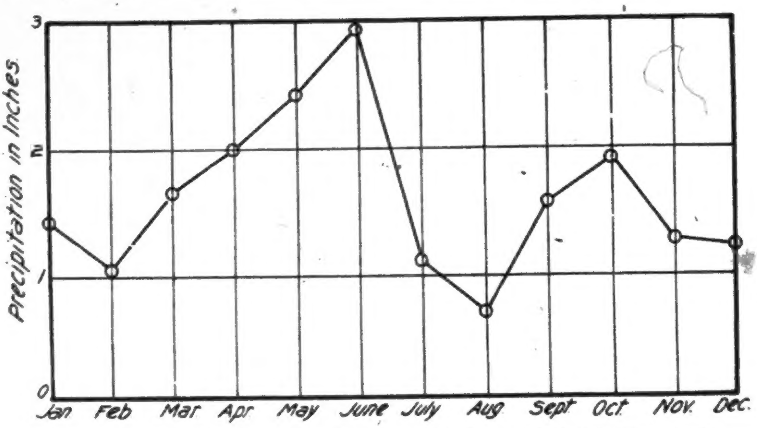

FIG. 2.—Mean monthly precipitation, Bozeman, Mont., January, 1880, to December, 1902.

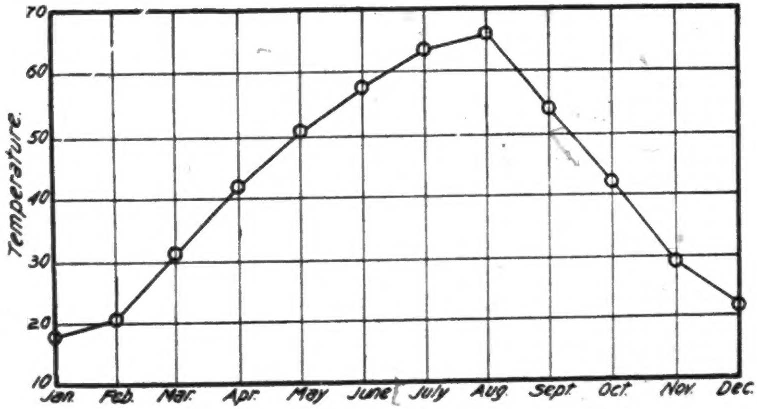

FIG. 3.—Mean monthly temperatures, Bozeman, Mont., 1880 to 1902.

The impression prevails in many States that the winter climate of Montana is very severe. This impression is not in accord with the mean monthly temperature records as indicated in figure 3 and given in the following table.

Average temperatures, 1880-1902.

	°F.
October	42.2
November	29.5
December	22.1
January	18.2
February	20.8
March	31.4

In the period under consideration there have been spells of intense cold. Five times in twenty-two years the mercury has gone below −40°, and on January 14, 1888, it registered −50°. On the other hand, the winter of 1901 was unusually mild and the lowest record was −14°.

The valley, for the most part being surrounded by mountains, is not subject to high winds. The lowest temperature is usually reached in a calm, clear night. The period of severe cold seldom lasts long. Rarely does the average minimum temperature for any winter month fall below zero, and on an average the temperature of 92.5 per cent of all the days in the year is above zero.

From the farmer's standpoint the worst feature of the climate is the comparatively short season between the late spring and the early autumn frosts. Frosts always occur in May and September. In ten out of the twenty-two years covered by the record there have been frosts in June; in one year there was frost in July, and in five years there were frosts in August. Of the frosts in June, July, and August 70 per cent have either been 2° or less of frost. Inasmuch as most plants can resist at least 1° below freezing it follows that the injurious effects of low temperature during the months named have not been great. Only once in twenty-two years has there been no frost in September. The September freeze may occur early in the month, in which case it occasionally injures late-sown wheat.

WEST GALLATIN RIVER.

This stream is by far the largest and most important tributary of the Gallatin drainage system. From its source in the northwest corner of the Yellowstone National Park it takes a northerly course in general, and for the first 65 miles of its course is confined to rough, mountainous country. At this point it leaves its canyon and enters the broad Gallatin Valley, through the western portion of which it takes a slight northwesterly course to the northern extremity of the valley, where it is joined by the East Gallatin River, flows westerly for a distance of 8 or 9 miles, and joins the Madison and Jefferson rivers at Three Forks, the three streams forming the upper Missouri River.

The drainage area of the West Gallatin River contains approximately 1,200 square miles. This area includes the basin of the river's valley tributaries in addition to that of the main stream itself. Of this 1,200 square miles, 876 square miles is tributary to the river above its point of entrance into Gallatin Valley. This rough, mountainous area lies at an elevation above sea level varying from 9,000 to 10,000 feet near Gallatin Lake in the Park to 5,200 feet at the mouth of West Gallatin Canyon. The greater part of this area lying below the timber line is covered with a heavy and luxuriant growth of forest and underbrush well calculated to conserve and protect the soil moisture, snowdrifts, and ice banks, from which the water supply of the river is drawn.

Like all mountain streams the West Gallatin derives its supply from a multitude of feeders and tributaries, both small and large, which head up in the mountains. In this discussion the West Gallatin tributaries have been divided into two classes, viz. the canyon tributaries and the valley tributaries.

The highest tributary of sufficient importance to be here considered is Taylors Fork or Dodge Creek, which enters from the west near the twenty-fifth mile of the river's course. As yet there is no irrigation from this creek, although during 1902 there were several filings made upon its waters. The land to be served lies along the creek bottom near the river. The elevation of the canyon in this vicinity is about 7,000 feet.

In the next 10 miles below Taylors Fork several fair-sized tributaries join the river. Among the important ones are Buffalo Horn, Cinnamon, Buck, and Elkhorn creeks. From only one of these streams, Buffalo Horn, is there any water diverted for irrigation. In 1899 a small ditch was taken out of this creek and with it about 200 acres of canyon land is said to be irrigated.

About 12 miles below Taylors Fork the river is joined from the east by Porcupine Creek and from the west near the same point by Beaver Creek. Some 3 miles below, West Fork, the largest tributary of the West Gallatin, enters from the west. The canyon, from a point a mile or so above Porcupine and Beaver creeks to the junction point of West Fork and the river, widens out and forms what is called the "Lower basin." This basin is about 3 miles long by 1 to 1.5 miles wide and is estimated to contain probably 2,000 acres of arable land, most of which could be irrigated. As yet there are but two small ditches taken out in the basin. One taps Porcupine Creek and serves about 200 acres of land on the east side of the river. The other takes its supply from West Fork and serves about 200 acres. Both of these are late ditches, the Waters ditch out of Porcupine Creek having been built in 1900, the Crail ditch out of West Fork being built in 1902. A ditch out of Beaver Creek is planned, construction to begin soon. This ditch is to serve about 1,000 or 1,200 acres of land lying on the west side of the river.

On leaving the lower basin the river again enters a narrow canyon and for 21 miles is confined by high mountain walls. All along the canyon course it is joined at short intervals by tributaries, both small and large. Near the lower end of the canyon it is joined from the east by Squaw Creek and from the west by Logger, Hell Roaring, and Spanish creeks. The last two creeks are among the important West Gallatin tributaries, Spanish Creek standing next in size to West Fork. In what is termed Spanish Creek Basin, lying along Spanish Creek and to the west of the West Gallatin Canyon, is a considerable area subject to cultivation. In this locality there are eight small ditches, varying in capacity from 50 to 300 miner's inches each, which tap Spanish Creek and distribute the water thus diverted to an area of land aggregating 2,000 acres. Some of these rights date back to 188[illegible] and 1886; the majority, however, have been acquired in recent years.

About 2 miles below Spanish Creek the river leaves the canyon and enters the Gallatin Valley, in which lie the lands which utilize the greatest part of its flow during the irrigation season. The valley tributaries of the West Gallatin are Wilson, Bear, Cottonwood, and Camp creeks. The first three join the river from the east about 4 miles below the mouth of the canyon. The last is of little importance as an irrigation stream. It rises in the low hills which separate the Gallatin and Madison basins and flows in a southerly direction, joining the river just above the junction of the West and East Gallatin rivers.

During the irrigation season the entire flow of the three creeks entering from the east is diverted for irrigation purposes. The land they serve lies on the benches to the east of the river. Cottonwood is the largest of the three creeks, having a drainage area of 40 square miles.

The following table shows the discharge of these creeks on different dates during the irrigation season of 1902. It was impossible to obtain suitable places of measurement above all ditches, so they were measured at the mouths of their respective canyons and the flow of all ditches diverting waters above the points of measurement was added. In the table are also given the discharges of some of the canyon tributaries of the West Gallatin. These measurements were made during the period of high water. For the sake of comparison the results of two measurements of the river, made June 9 and 14 at Williams bridge, about 1 mile below the mouth of the canyon, are included in the table.

Discharge of West Gallatin tributaries, 1903.

Name of tributary.	Date of measurement.	Discharge.	
		Cubic feet per second.	Miner's inches.
Cottonwood Creek	June 3	128.02	5,120.8
Do	June 23	127.72	5,108.8
Do	July 10	64.48	2,579.2
Do	Aug. 13	32.63	1,305.2
Bear Creek	June 8	46.91	1,876.4
Do	June 28	27.50	1,100.0
Do	July 10	12.94	517.6
Do	July 13	7.07	282.8
Wilson Creek	June 3	22.18	887.2
Do	July 10	8.68	347.2
Do	Aug. 13	4.44	177.6
Spanish Creek	June 10	464.33	18,573.2
Do	July 17	163.59	6,543.6
Logger Creek	June 10	5.51	220.4
Hell Roaring Creek	do	306.76	12,270.4
Do	June 18	91.69	3,667.6
Squaw Creek	June 11	137.65	5,506.0
Swan Creek	do	142.70	5,708.0
Moose Creek	do	52.50	2,100.0
Portal Creek	do	160.00	6,400.0
Dudley Creek	do	77.96	3,118.4
West Fork	June 12	607.81	24,312.4
Waters ditch (Porcupine Creek)	do	1.78	71.2
West Gallatin River at Williams bridge	June 9	4,361.22	174,448.8
West Gallatin River	June 14	4,767.81	190,712.4

Like all mountain streams whose flow is derived from melting snows high up in the mountains, the West Gallatin is subject to a large flood flow during the spring season, estimated by the United States Geological Survey to reach in some years 4.5 times the average normal discharge.

Following is a summary of the observations made by the United States Geological Survey at Williams bridge for a period of six years, 1896 to 1901, inclusive:

Annual discharge of West Gallatin River at Williams bridge, 1896–1901.

Year.	Maximum.	Minimum.	Mean.	Total.	Run-off.	
					Depth.	Per square mile.
	Cu. ft. per sec.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Acre-feet.*	*Inches.*	*Cu. ft. per sec.*
1896	10,750	100	1,132	817,824	17.66	1.31
1897	5,780	350	993	922,396	15.71	1.15
1898	7,226	560	1,328	961,231	20.96	1.55
1899	9,760	650	1,570	1,148,039	24.78	....
1900	5,410	280	991	718,260	15.67	1.15
1901	5,058	435	....	....	....	....

The actual minimum flow of the rivers for the years given above is somewhat greater than that noted, as five ditches head on the river above the gauging station. During the irrigation season the combined flow of those five canals would probably reach 120 or 125 cubic feet per second.

From the mouth of the canyon to a point on the river about 25 miles below the river has an average fall of 32 feet per mile, and its channel is subject to very little change. This makes tapping the river comparatively easy. In the 25 miles there are no less than fifty-four ditches taking water from the river. These ditches, especially those built some years ago, are for the most part small, having been built by the irrigators themselves, three, four, or half a dozen farmers joining in the construction of a common ditch. Most of the ditches of this class were built for the irrigation of lands lying contiguous to the river bottom, and little or no difficult work was encountered.

When the higher valley lands were settled several large canals were constructed which take their supply well up on the river.

USE OF WATER.

DIVERSION AND DISTRIBUTION.

Not in the history of irrigation from the West Gallatin has there ever been any regulation as to the extent of the diversions made because in normal seasons the river's supply has been sufficient to meet all demands. But during seasons of short supply, only one or two of which have as yet been experienced, the supply while sufficient, had proper division been made, was not equal to the demands, and on the lower part of the streams a severe shortage was felt, and a stage is being reached where the demand will more often exceed the supply and the old régime will have to give place to some system of stream control.

The methods of distributing water from the larger canals to consumers have not reached a settled state. On the West Gallatin Irrigation Company's two canals the amounts diverted by laterals are computed by a hydraulic formula. The factors necessary are, first, size of opening of the lateral head gate; second, head of water in canal over opening; and, third, the velocity of flow through opening, which is obtained for different heads from Trautwine's Engineering Handbook. The actual discharge is assumed to be 70 per cent of the theoretical discharge derived from the above factors. All discharge measurements are expressed in Montana inches.

On the Kleinschmidt canal, within the last year, the current meter has been adopted. Up to the time of its adoption the diversions by laterals were in the majority of cases left to the ditch rider, whose estimate of a lateral's discharge was accepted as the probable flow.

On the Farmers canal trapezoidal weirs have been constructed in the laterals near their points of diversion. But for want of proper care in their maintenance they are in the majority of cases in poor condition, and are but little better than no measuring device at all.

On the Kughen ditch and a majority of other larger ditches no system of measurement is employed, the amount diverted by the laterals being left to the discretion of the ditch walker or to the irrigators themselves.

On the smaller ditches taking water from the river, where only a few parties are interested, no measured division of the ditches' supply is made, each person taking an amount proportionate to his needs.

METHODS OF IRRIGATION.

The methods of applying water to crops irrigated from the West Gallatin are in every way similar to those employed in other sections of the State and are described in another part of this report. (See pp. 43-51.)

FLOW OF RIVER AND CANALS.

During the season of 1902, along with other field observations made in the Gallatin Basin, a series of measurements was made of all the canals and ditches taking water from the West Gallatin. One set of measurements was made during the middle of June at a time when a majority of the canals were diverting their greatest volume. This measurement was made some three or four weeks after the irrigation season had opened. A second set of measurements was made about the middle of July, and a third set of measurements was made about the middle of August. This last measurement represents the flow at the termination of the irrigation period. In the two tables which follow are given the results of these three sets of measurements. Those in the first table give the discharge of the canals on the east side of the river in the order in which they head on the river. The second table gives in a similar order the discharge of all canals on the west side of the river.

As the statute inch is used extensively in Montana in the statement of stream discharges, the values in the following tables have been expressed both in cubic feet per second and in Montana inches, 40 of which are equivalent to 1 cubic foot per second.

Discharge of canals on east side of West Gallatin River, 1902.

Name of canal.	June 14-20.		July 15-18.		August 14-16.		Mean flow for season.	
	Cubic feet per second.	Miner's inches.	Cubic feet per second.	Miner's inches.	Cubic feet per second.	Miner's inches.	Cubic feet per second.	Miner's inches.
Kleinschmidt	79.27	3,170.8	101.81	4,072.4	98.01	3,920.4	96.03	3,841.2
Bush	7.28	291.2	15.24	609.6	4.43	177.2	9.89	395.6
Ralph	0.00	0.0	2.87	114.8	.89	35.6	2.21	88.4
Farmers, or Excelsior	168.22	6,728.8	193.46	7,738.4	116.11	4,644.4	167.89	6,715.6
Ferris	26.27	1,050.8	12.22	488.8	11.99	479.6	17.79	711.6
Middle Creek supply	58.85	2,354.0	39.94	1,597.6	35.53	1,421.2	46.60	1,864.0
Accola	6.29	251.6	3.72	148.8	0.00	0.0	5.00	200.0
Beck, Border, Spring & Matthews	12.90	483.6	32.00	1,280.0	10.78	431.2	19.79	791.6
Bicketts—Tudor & Nieble	5.16	206.4	4.35	174.0	1.59	63.6	4.12	164.8
Spain	28.37	1,134.8	31.48	1,259.2	8.70	348.0	25.68	1,027.2
Waterman	9.25	370.0	.33	13.2	5.83	233.2	4.99	199.6
Ketterer, Owenhouse & Stephens	43.49	1,739.6	18.39	735.6	14.60	584.0	27.67	1,106.8
Knadler, ¼: Foerschler, ¼	8.94	357.6	12.49	499.6	15.30	612.0	11.63	463.2
Stephens & Creasy	14.14	565.6	11.16	446.4	3.58	143.2	10.83	433.2
Weaver & McDonald	8.32	332.8	19.16	766.4	6.92	276.8	12.37	494.8
Knadler, White & Knadler	.75	30.0	.50	20.0	1.15	58.0	.79	31.6
Hoffman, Stephens & Cook	8.87	354.8	15.17	606.8	6.60	264.0	10.93	437.2
Weaver & Stone	4.79	191.6	.75	30.0	5.32	212.8	3.28	131.6
Learmouth, Ferguson, Patterson & Owenhouse	8.86	354.4	4.19	167.6	17.41	696.4	8.70	348.0
Hoffman & Marks	10.83	433.2	5.22	208.8	2.61	104.4	6.94	277.6
Bell, Franks & Creasy	11.04	411.6	2.10	84.0	1.79	71.6	5.61	224.4
Old Creamery or Cockrill ditch	9.54	381.6	5.92	236.8	1.78	71.2	6.54	261.6
Dawes Bros. & Porter	13.21	528.4	1.73	69.2	.75	30.0	6.12	244.8
Gibson & Green	.50	20.0	0.00	0.0	0.00	0.0	.50	20.0
Total	545.14	....	534.20	....	371.97	....	511.90	....

Discharge of canals on west side of West Gallatin River, 1902.

Name of canal.	June 14-20.		July 15-18.		August 14-16.		Mean flow for season.	
	Cubic feet per second.	Miner's inches.	Cubic feet per second.	Miner's inches.	Cubic feet per second.	Miner's inches.	Cubic feet per second.	Miner's inches.
Williams No. 1	....	....	5.09	203.6	1.78	71.2	3.99	159.6
Williams No. 2 (lower)	21.89	875.6	12.87	514.8	6.31	252.4	15.16	606.4
Cockrill	5.09	203.6	2.05	82.0	.50	20.0	2.95	118.0
Todd	....	....	3.10	124.0	1.38	55.2	1.51	60.4
West Gallatin (high line)	100.10	4,004.0	106.19	4,247.6	46.02	1,840.8	91.72	3,668.8
Sterling	8.56	342.4	3.52	140.8	7.59	303.6	6.35	254.0
Le Beau	20.68	827.1	8.09	323.6	.62	24.8	11.63	465.2
Railey	0.00	0.0	3.16	126.4	.30	12.0	2.21	88.4
Gabriel	1.69	67.6	2.49	99.6	3.35	134.0	2.34	93.6
West Gallatin (short line)	21.57	862.8	26.29	1,051.6	12.87	514.8	21.72	868.8
Cameron or Kughen	58.80	235.2	76.11	3,044.4	32.82	1,312.8	60.53	2,421.2
Cameron, Nieble, Corrie & Clark	16.89	675.6	15.96	638.4	3.67	146.7	13.87	554.8
Corrie	1.50	60.0	.30	12.0	.80	32.0	.88	35.2
Davidson, Leach, Smith & Heiskell	48.02	1,920.8	20.18	807.2	5.56	322.4	28.39	1,135.6
Lewis	31.73	1,269.0	8.43	337.4	17.05	682.0	19.45	778.8
Holgate & Grove	8.62	344.8	2.83	113.2	2.61	104.4	5.10	204.1
Holgate lateral No. 1	1.77	70.8	2.48	99.2	1.71	68.4	2.04	81.7
Holgate lateral No. 2	.40	16.0	0.00	0.0	1.88	75.2	.54	216.0
Manhattan or Moreland	23.05	922.0	11.87	474.8	23.14	925.6	18.59	743.6
Patterson & Boss	12.66	506.4	5.14	205.6	0.00	0.0	8.90	356.0
White or Cayuse	29.30	1,171.9	31.44	1,257.5	4.56	182.4	25.21	1,008.4
Buckley, Curtis & Holgate	10.49	419.6	8.30	332.0	5.20	208.0	8.55	342.0
Lamphear & Bryan	10.48	419.2	4.21	168.4	5.14	205.6	6.90	276.0
Heeb No. 1	3.33	133.2	1.20	48.0	5.76	230.4	2.96	118.4
Heeb No. 2	11.89	475.6	8.83	353.2	6.24	249.6	9.53	381.2
Heeb No. 3	1.75	70.0	1.35	54.0	.95	38.0	1.35	54.0
Cruse No. 1	1.00	40.0	6.11	244.4	3.05	122.0	3.45	138.0
Cruse No. 2	0.00	0.0	1.24	49.6	1.75	70.0	1.50	60.0
Lower Manhattan	22.20	888.0	22.65	906.0	0.00	0.0	22.42	896.8
Baker	8.33	333.2	4.14	165.6	1.68	67.2	5.32	212.8
Total	481.79	....	405.62	....	204.29	....	405.06	....

The values in the column headed "Mean flow for season" have been derived from the measurements given in the other columns. The measurements made in August, however, were given only one-half the weight of those made in June and July.

By cooperating with the representatives of the United States Geological Survey a daily record of the flow of the West Gallatin at Williams bridge for the months of the irrigation season was obtained. The flow of the river at this point in both cubic feet per second and Montana miner's inches is given in the following table:

Discharge of West Gallatin River at Williams bridge, Gallatin Valley, Montana, 1902.

	May.		June.		July.		August.		September.	
Day of month.	Cubic feet per second.	Miner's inches.	Cubic feet per second.	Miner's inches.	Cubic feet per second.	Miner's inches.	Cubic feet per second.	Miner's inches.	Cubic feet per second.	Miner's inches.
1	500	20,000	5,000	203,600	1,530	61,200	810	32,600	500	20,000
2	500	20,000	3,220	128,800	1,665	66,000	755	30,200	475	19,000
3	450	18,000	2,775	111,000	1,737	69,480	700	28,200	450	18,000
4	450	18,000	2,605	104,200	1,530	61,200	700	28,200	450	18,000
5	450	18,000	2,605	104,200	1,415	56,600	700	28,200	400	15,200
6	500	20,000	2,605	104,200	1,415	56,600	650	26,000	400	15,200
7	600	24,000	3,130	125,200	1,310	52,200	650	26,000	400	15,200
8	650	26,000	4,887	195,280	1,263	50,480	650	26,000	360	14,200
9	810	32,600	5,225	212,200	1,215	48,800	650	26,000	360	14,200
10	982	39,280	5,000	203,600	1,215	48,800	600	24,000	360	14,200
11	1,060	42,400	5,000	203,600	1,215	48,800	600	24,000	360	14,200
12	1,175	47,080	4,325	173,000	1,215	48,800	550	22,000	360	14,200
13	1,472	58,880	4,325	173,000	1,263	50,480	600	24,000	360	14,200
14	1,885	75,400	4,213	168,480	1,263	50,480	600	24,000	360	14,200
15	2,690	107,600	3,595	143,200	1,310	52,200	600	24,000	450	18,000
16	2,120	84,800	2,605	104,200	1,310	52,200	600	24,000	400	15,200
17	1,885	75,400	2,445	97,800	1,310	52,200	600	24,000	400	15,200
18	1,597	63,800	2,445	97,800	930	37,200	550	22,000	450	18,000
19	1,415	56,600	2,285	91,400	1,135	45,400	550	22,000	450	18,000
20	1,175	47,080	1,960	78,400	1,135	45,400	550	22,000	450	18,000
21	1,028	41,240	1,960	78,400	995	39,800	550	22,000	450	18,000
22	1,060	42,400	2,040	81,600	995	39,800	550	22,000	400	15,200
23	1,215	48,800	2,285	91,400	995	39,800	550	22,000	450	18,000
24	1,472	58,880	2,365	94,600	995	39,800	500	20,000	450	18,000
25	1,472	58,880	2,285	91,400	995	39,800	500	20,000	450	18,000
26	1,960	78,400	2,445	97,800	995	39,800	500	20,000	450	18,000
27	2,525	102,080	2,120	84,800	995	39,800	500	20,000	450	18,000
28	3,997	159,880	1,960	78,400	995	39,800	500	20,000	450	
29	4,663	186,480	1,530	61,200	870	34,800	500	20,000	450	
30	5,338	216,480	1,530	61,200	870	34,800	500	20,000	450	
31	5,565	229,400			870	34,800	500	20,000		

Figure 4 shows the amount of water diverted from West Gallatin River by all of the ditches and canals from June 10 to August 20, 1902, and the discharge of the river during that time. In comparing the amount diverted with the discharge in the river at Williams bridge, it is found that there was enough for all purposes. It should be kept in mind, however, that there was more than the average flow in this river in 1902. The discharge of the river from July 5 to August 20, 1900, was insufficient to furnish for all the ditches and canals the volumes diverted in the summer of 1902, and the same condition prevailed in 1901 from July 8 to August 20.

DUTY OF WATER UNDER WEST GALLATIN RIVER.

The irrigation season in the Gallatin Valley extends from about the middle or last of May until about August 15. There are, of course, localities where irrigation of some crops is begun before the middle of May, and where the season lasts beyond the middle of August. In such cases, however, the crop raised is usually not one of the regular crops of the valley, for these almost without exception receive the irrigation they require in the period mentioned. In many cases, although water is turned into the canals anywhere from the 1st to the 15th of May, extensive irrigation does not begin until in the forepart of June, depending almost entirely of course on the nature of the season, whether early or late.

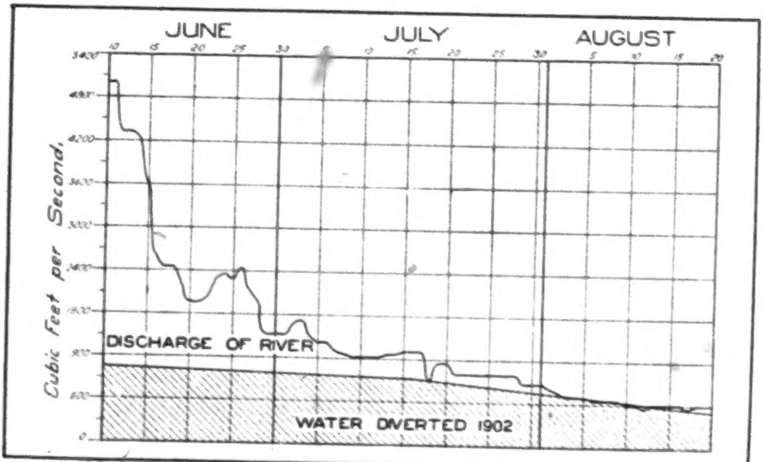

Fig. 4.—Discharge of West Gallatin River, 1902, and diversions therefrom.

The first crops to receive water in the spring are pastures and meadows, clover and alfalfa, after which the grain is watered. As grain is the main crop of the valley, irrigation occupies a large part of the season. After the grain is sufficiently watered and the first hay crop is cut, the water is again applied to the clover and alfalfa land for the second hay crop.

In the majority of cases alfalfa and clover receive but one watering for each crop, grain receiving from one to three waterings, according to the locality. The number of waterings depends of course largely on the rainfall both as to its amount and as to the time it is received. During the season of 1902 the rainfall came in sufficient amount and at such time as to make but one irrigation necessary for each crop of clover. Grain was well along also before irrigation became necessary.

During the spring of 1902 a series of investigations of the duty of water on West Gallatin River was instituted under some of the representative canals, and also a study of seepage losses from these canals as affecting the duty of water. Other studies were also carried on which had a direct bearing on these two phases of the investigations. The studies were confined to three canal systems which were chosen with special regard to their location, and for the reason that the conditions encountered under each system varied widely from those of the other systems, the three, however, representing nearly all the varying conditions of soil, methods of irrigation, and canal management to be found in the valley of the West Gallatin River.

The largest canal chosen for the investigation was the High Line canal, belonging to the West Gallatin Irrigation Company. This system was taken as representative of the larger incorporated canals, which head high up on the river and carry water for several miles before it is distributed to laterals. As a representative of the medium-sized cooperative canal, which conveys its water but a short distance before being used, thus eliminating any large seepage losses, the Kughen ditch was chosen. The third ditch was the Weaver and Stone ditch, representative of the small, private or individual ditch, heading on the lower section of the river.

Before the irrigation season opened recording instruments were installed on each of the canals, and throughout the season a continuous record of the amount of water flowing through each canal was obtained.

DUTY OF WATER UNDER HIGH LINE CANAL.

The register was installed in this canal on the Todd flume, about 2.5 miles below the head. At this point the canal crosses a narrow ravine in a flume about 30 feet long by 13.5 feet wide. In the following table is given the monthly flow from May 24 to August 31, inclusive, in cubic feet per second, Montana miner's inches, and acre-feet:

Discharge of West Gallatin High Line canal, 1902.

Month.	Average flow.		Discharge.
	Cu. ft. per sec.	*Miner's inches*	*Acre feet.*
May (24-31)	35.8	1,432	569
June	60.8	2,432	3,619
July	90.4	3,616	5,556
August	44.4	1,776	2,728
Season	62.9	2,516	12,472

According to the annual report of Mr. E. C. Kinney, superintendent of the West Gallatin Company, there were 2,343 acres of land actually irrigated under the High Line canal. The duty given in the following summary is based on this estimate.

Quantity of water applied to lands under High Line canal, 1902.

Duration of irrigation season		May 24–August 31
Area irrigated	acres..	2,343
Water received by land	acre-feet..	12,472
Depth of water used in irrigation	feet..	5.32
Depth of rainfall during season[a]	do....	.39
Total depth of water received by land	do....	5.71

The average flow of the canal at Todds flume was 62.9 cubic feet per second, or 2,516 miner's inches, giving a duty of water of 37 acres per cubic feet per second, or approximately 1 acre per inch.

The above values are based on the amount diverted from the river. In order to determine the amount of water applied to the land, seepage losses must be taken into consideration. During the season of 1902 seepage measurements were made on the High Line canal, with a view to determining the loss in different sections of the canal. In the following summary is given the result of the seepage test made in June, 1902.

Seepage in first 10 miles of High Line canal, measured June 24, 1902.

[In cubic feet per second.]

Discharge 0.5 mile below head gate	98.67
Discharge 1 mile tunnel	87.47
Loss in 10 miles	11.20
Loss per mile	1.12
Percentage of loss	11.35

In this first 10 miles there are no diversions. The canal traverses a steep sidehill almost the entire distance, gaining the top of the bench near the point where the lower measurement was made. On July 18, 1900, the seepage loss, measured in this same section when the discharge was 114.5 cubic feet per second at the head, was found to be 12.9 per cent of the amount entering the head. The loss in the next 16 miles was determined June 25. The results appear in the following table:

Seepage loss from High Line canal between mileposts 11 and 27 June 25, 1902.

[In cubic feet per second.]

Discharge near 11-mile post			89.69
Discharge near 27-mile post		19.87	
Diversions in section		54.71	
Total outflow from section			74.58
Loss in 16.5 miles			15.11
Loss per mile			.92
Percentage of loss	per cent..		16.85

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[a] Rainfall, assumed to be same as at Government Weather Bureau station, Bozeman.

The loss in this same section of canal as determined on July 19, 1900, was found to be 15.13 cubic feet per second when the discharge at the head of the section was 99.56 cubic feet per second.

Based on the measurements made in 1902, the seepage loss in the 26.5 miles of canal measured would be as follows:

Seepage loss in 26.5 miles of High Line canal, June 24-25, 1902.

[In cubic feet per second.]

Discharge at point 0.5 mile below head		98.68
Discharge near 27-mile post	19.87	
Diversions in section	54.71	
Total outflow from section		74.58
Loss		24.10
Correction due to change in flow of canal		2.22
Total loss in 26.5 miles		26.32
Loss per mile		.99
Percentage of loss per cent		26.67

Taking this 26.67 per cent as representing loss in transmission in main canal line, and disregarding losses in distributary laterals, we have as the depth of water on the 2,343 acres irrigated during 1902 4.19 feet.

DUTY OF WATER UNDER KUGHEN DITCH.

The rating flume on the Kughen ditch is located about 0.5 mile below the head of the canal and about 300 yards above where the first lateral takes water from the ditch. As there was no suitable structure on the canal which would answer as a rating flume, a new flume was placed in the canal. The section of the canal both above and below the flume for a distance of 100 to 200 yards is in splendid condition as to alignment and cross section. The flume is 14 feet long by 10 feet wide and so placed that little or no eddying is caused either by the waters entering or leaving the flume. The average depth of water in the flume when the canal was carrying its normal amount was about 2.5 feet.

This flume was provided with recording register and was carefully rated during the season. The daily flow from June 4 to August 16, inclusive, a period of seventy-four days, is summarized in the following table:

Discharge of Kughen ditch, 1902.

Month.	Average flow.		Discharge.
	Cu. ft. per sec.	*Miner's in.*	*Acre-feet.*
June (4-30)	49.4	1,976	2,646
July	58.6	2,344	3,603
August (1-16)	33.7	1,348	1,079
Season	49.9	1,996	7,328

The area irrigated during the season was obtained by a survey made for that purpose. Care was taken to eliminate all waste land, so that results obtained should represent the exact area devoted to crops.

In the following table is given the area devoted to the various crops raised on each farm entitled to water from the ditch:

Area of crops irrigated under Kughen ditch, 1902.

Name.	Barley.	Wheat.	Oats.	Flax.	Clover.	Timothy.	Pasture	Summer fallow.	Total acreage.
	Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
Green Young	81.50	12.39					5.97	72.53	172.39
Joe Johnson	70.22		72.79					169.20	312.21
G. G. Johnson	37.52		231.16			43.62		195.14	407.44
D. Cameron	107.90		23.42				16.53	140.74	288.59
J. B. Corrie				121.68				110.88	232.56
William Lawrence							2.75	87.60	90.35
Frank Heiskell	160.80				3.44			117.09	281.33
T. E. Kirk	182.29							203.64	385.93
Catherine E. Clark	75.76								75.76
Mrs. A. J. Rowland	95.28							145.32	240.60
Mathias Nieble	87.80		56.24					136.58	280.62
Mary E. Matthews			39.02						39.02
J. White Place						36.77			36.77
Total	899.07	12.39	422.63	121.68	3.44	80.39	25.25	1,378.72	2,943.57

Deducting the 1,378.72 acres of summer-fallowed land, which received no water during the season, gives the area devoted to irrigated crops as 1,564.85 acres. Of this area over half was devoted to barley and the greater part of the remainder to oats, less than one-tenth the area producing hay crops.

The following summary shows the duty of water as based upon the area given above:

Duty of water under Kughen ditch, 1902.

Duration of irrigation season, June 4 to August 16	days	74
Area irrigated	acres	1,564.85
Water received by land	acre-feet	7,328.00
Depth of water used in irrigation	feet	4.68
Depth of rainfall	do	.33
Total depth of water received by land	do	5.01

Based on a period of seventy-four days, the average flow in the canal at the rating flume was 49.9 cubic feet per second, showing a duty of 31.34 acres per cubic foot per second; 1 inch was used for every 0.78 acre. As the water is used near the head of the ditch no correction need be made for seepage losses.

DUTY OF WATER UNDER WEAVER AND STONE DITCH.

As mentioned previously the Weaver and Stone ditch is representative of the small cooperative ditches which are quite numerous on the West Gallatin. It heads on the east side of the river 6 miles below the head of the Kughen ditch. From the point of diversion the ditch flows almost due north for a distance of 4.5 miles, where it reaches the two farms on which its waters are used. The rating flume in this canal was placed about 100 yards below the head of the ditch. The flume was made 8 feet long by 4.7 feet wide and was provided with a recording register. The season's record covered a period of seventy-seven days, extending from June 1 to August 16. The discharge of the ditch is summarized in the following table:

Discharge of Weaver and Stone ditch, 1902.

Month.	Average flow.		Discharge.
	Cu. ft. per sec.	*Miner's in.*	*Acre-feet.*
June	9.34	374	556
July	5.58	223	343
August (1-16)	7.15	286	228
Season	7.38	295	1,127

Only portions of the Weaver and Stone farms require irrigation, the remainder being sufficiently moist by reason of seepage waters from irrigated lands above. In order to obtain the acreage subject to irrigation during the season of 1902 a stadia survey was made. The results of this survey appear in the following table:

Irrigated lands under Weaver and Stone ditch, 1902.

Name.	Barley.	Wheat.	Oats.	Clover.	Alfalfa.	Wild hay.	Total.
	Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
A. D. Weaver		74.69	4.59	3.21	23.13		105.62
D. Stone	38.12				40.18	17.22	95.52
Total	38.12	74.69	4.59	3.21	63.31	17.22	201.14

The total discharge for the season would cover this area to a depth of 5.56 feet. The average flow at the rating flume during the seventy-seven days of record was 7.38 cubic feet per second, making the duty of water 27.25 acres for each cubic foot per second, or 0.68 acre per inch.

A measurement to determine seepage losses in the long supply canal was made during the latter part of the season. This measurement showed that when there was a discharge of 4.52 cubic feet per second, the long transmission in the small ditch, without either uniform grade or cross section, caused a loss of approximately 50 per cent. When this is taken into consideration, the depth of water received by the Weaver and Stone farms is 2.78 feet. This is a duty of 54.5 acres per cubic foot per second, or 1.36 acres per inch.

WATER RIGHTS IN THE WEST GALLATIN BASIN.

Permanent settlement of the Gallatin Basin began in July, 1864, at which time J. M. Bozeman, the pioneer of the Bozeman route to the North Platte River, founded Bozeman, the county seat of Gallatin County. Since that time settlement has increased steadily until at the present time the entire cultivable area of the valley section is under private ownership, and, with the exception of a few scattering tracts in the mountainous section, no land is now open for settlement, the only means of acquirement being by purchase.

During the period of development, covering a space of nearly forty years, water for the irrigation of the lands of the valley has been taken promiscuously from ~~the~~ many streams, both large and small, which enter the valley. Until within the last few years water has been diverted from the various streams without let or hindrance.

The lands first to be reclaimed were those which were the easiest of cultivation and upon which water could be conveyed with but little difficulty. Such lands, almost without exception, were located on the lower parts of the streams, and it is in these sections that the oldest rights are found. As settlement of the valley increased, lands higher up on the stream were brought under cultivation and ditches were taken from the streams at the most convenient points.

The first ditches built were small, being individual or small cooperative enterprises. After all the easily available land had been brought under irrigation by these small systems, incorporated canal companies were formed which planned, and in a few instances constructed, large canal systems which head well up on the larger streams and by following long circuitous routes have been able to supply the higher bench lands. As no system of stream control existed, these diversions increased unrestrictedly from year to year until a slight shortage was felt by the irrigators on the lower part of the streams. When this stage was reached the lower irrigators, determined not to be thus deprived of their water supply, moved the heads of their ditches upstream to points where the river's supply was not so greatly depleted. On the same theory the next higher irrigator, when a shortage began to be felt, moved his head gate upstream also. As a result we have at the present time a system, especially noticeable on the West Gallatin River, in which numerous small individual and partnership ditches serve farms which lie anywhere from 2 to 6 miles below the points of diversion. These long parallel ditch lines, in addition to having required an immense amount of uncalled-for labor in their construction, are very ineffective as water carriers and lose by seepage in transit from 25 to 60 per cent of the amounts diverted. The scheme, therefore, which was originally intended to increase the water supply for the lower irrigators, has really been of little benefit to them, and has certainly been a serious drawback to the irrigated section in general.

The present condition is but a development of the conditions described above, only complicated somewhat by one or two recent years of short water supply. The man on the lower end of the stream claims those above him are using more water than their just share, while the man above says he has no more than he needs, but the large incorporated canals divert water in excess of their rights or needs, and allow the surplus to run back into the river at the ends of their canals too low down on the stream for subsequent diversion. The officers of the larger canals say there is water enough for all if only economical use is practiced. Meanwhile new appropriations are being made each year higher and higher on the tributaries. On some of the streams the day is long passed when the abundance of the supply served to prevent litigation, notably on Middle Creek.

The necessity for litigation arises from the fact that rights are acquired without public supervision and therefore without public records. While their existence is unquestioned, under existing laws they must remain undefined either as to volume or time until defined by the courts as a result of litigation between claimants. Naturally such litigation will not arise until the supply of water is insufficient to supply all demands.

In 1885 a law was enacted requiring all parties wishing to acquire rights to water to post notices stating the number of inches claimed; the purpose for which it is claimed; the place of intended use; the means of diversion, with size of flume, ditch, pipe, or aqueduct by which he intended to divert it; the date of appropriation, and the name of the appropriator. Within twenty days a copy of this notice, with the name of the stream and accurate description of the point of diversion, must be filed with the county clerk and verified by the affidavit of the appropriator or some one in his behalf. Within forty days after posting work must be begun, and must be prosecuted with reasonable diligence to completion. "If the ditch or flume when constructed is inadequate to convey the amount of water claimed in the notice aforesaid, the excess claimed above the capacity of the ditch or flume shall be subject to appropriation by any other person." If this law is complied with the right to the use of water relates back to the date of posting the notice.

It will be seen that the notice provided for is posted and filed before the work is begun and that the beginning of the work within forty days and its diligent prosecution to completion are necessary to the acquirement of a right, and that this right is limited by the capacity of the works, not by the amount claimed. The record, therefore, is evidence of the intention of the claimants only, and not in any way an index of the rights acquired.

The same law provided that those who had acquired rights previous to its passage should within six months file with the county clerks declarations in writing containing the same facts required in the notices previously referred to, "*Provided*, That a failure to comply with the requirements of this section shall in no wise work a forfeiture of such heretofore acquired rights, or prevent any such claimant from establishing such rights in the courts." This section is inoperative, because without the last clause it would be void and with it the record will be incomplete. The only value these records have is as "prima facie evidence of the statements therein contained." With a view to determining the completeness and the accuracy of this record, especially that portion relating to the rights in the Gallatin Basin, a careful and complete investigation was made of the entire record on file in the recorder's office of Gallatin County. The complete record occupies parts of 15 large volumes and contains between 2,000 and 3,000 recorded notices of appropriation and claims to water. Some of these records date back to the time when Gallatin County extended as far to the east as Billings and Miles City, and embraced the territory which now comprises the counties of Park, Sweetgrass, Carbon, Yellowstone, Rosebud, and Custer. Among the early records were found claims to water from such streams as the Musselshell and the Yellowstone rivers. Some of these old claims dated back to the "sixties" and represented some of the oldest rights on these streams.

Until within the last few years it was the custom to record all claims and notices of appropriation in the miscellaneous record and index it only as such. Within recent years, however, separate books have been provided for the water record, and in these have been placed all the notices and claims relative to the appropriation of water. This record is quite complete and easy of access.

In the following table are given the abstracts of the Gallatin Basin record, classed according to the stream on which the claims were made. The claims have been grouped according to the main stream and its tributaries, and are divided into "definite" and "indefinite" claims. The former contains all claims in which the amount of water is expressed in miner's inches or cubic feet per second, while the latter contains all claims in which the amount was expressed in indefinite terms, such, for instance, as "all the stream," "all this ditch will carry," "all this ditch takes," "sufficient for my land," and many similar expressions. The claims given for the West Gallatin River, Middle Creek, Bozeman Creek, East Bear or Flannery Creek, Rocky Canyon Creek, Bridger Creek, and the East Gallatin River are claims to water from the main streams themselves. The claims on the tributaries of these main streams are indented under the main streams.

Summary of recorded claims to water, Gallatin Basin.

Name of stream.	Definite claims.		Indefinite claims.	
	Number.	Amount.	Number.	Amount.
		Miner's ins.		
West Gallatin and tributaries	118	315,456	24	Various.
Cottonwood Creek (south)	11	7,590	2	Not given.
Bear Creek (west)	10	6,195	5	Claim all.
Wilson Creek	4	600		
Middle Creek	29	14,300	4	Not given.
Bozeman Creek	29	17,570	1 1	Claim all. Not given.
East Bear or Flannery Creek	14	4,161		
Rocky Canyon Creek	23	10,926	1	Do.
Bridger Creek	9	1,590	5 1 1	Claim all. Not given. One-third of stream.
Lyman Creek	11	2,460	6	Claim all.
Spring or Churn Creek			2	All of stream.
Cottonwood Creek	2	800		
Bostwick Creek	3	200	1	Not given.
Springhill or Ross Creek	17	15,610	4	All of stream.
Reese Creek	5	1,600	1	Do.
Dry Creek (north)	12	2,145	2	All; not given.
Dry Creek (south)	1	150	1	All of stream.
Doc Corran Creek			1	Not given.
East Gallatin River	8	3,147.5	7	Do.
Springs and creeks (not definitely located)	50	12,399	21	Various.

The foregoing table represents the entire water-right record of the Gallatin Basin, which comprises some 450 notices of appropriation and claims to water. As mentioned previously, this record can not be taken as a guide to existing rights for the reason that probably not to exceed one-half of the claims were followed by diversions, and for the further reason that probably not over two-thirds of the actual appropriators in the basin, taking the record of the West Gallatin River as a criterion, have ever had their rights recorded, the other third choosing to trust to diversion and use to validate their rights rather than go to the expense of recording their rights when such procedure guaranteed neither security of title nor immunity from litigation.

To bring out the extent to which the streams of the Gallatin Basin have been overappropriated or rather overclaimed, the data taken from the records and the results of the season's stream measurements have been brought together in the table which follows. It must be remembered that the values given under the head "Amount claimed" are only the amounts recorded in definite terms and do not include the large proportion of unrecorded rights or the rights which are recorded but do not have the amount claimed expressed in definite terms. The stream measurements, as mentioned in another part of this report, were made at points on the respective streams where their maximum flow would be encountered. The values given for stream flow are the averages of the measurements made during the irrigating season, which include both high and low water measurements.

Comparison of the definite claims to water, with the average discharge of streams of Gallatin Basin, season 1902.

Name of stream.	Number.	Amount.	Average discharge.	
		Miner's ins.	*Miner's ins.*	*Cu. ft. per sec.*
West Gallatin and tributaries	118	315,456	56,125	1,403.12
Cottonwood Creek (south)	11	7,590	3,528	88.21
Bear Creek (west)	10	6,195	944	23.61
Wilson Creek	4	600	353	8.83
Middle Creek	29	14,300	4,680	117.01
Bozeman Creek	29	17,570	1,412	35.29
East Bear or Flannery Creek	14	4,161	482	12.04
Rocky Canyon Creek	23	10,926	1,425	35.62
Bridger Creek	7	1,590	3,806	95.16
Lyman Creek	11	2,460	443	11.07
Cottonwood Creek	2	800	282	7.05
Springhill or Ross Creek	17	15,610	1,738	43.46
Reese Creek	5	1,600	930	23.26
Dry Creek (north)	12	2,145	282	7.05

On West Bear Creek, in addition to the definite claims, amounting to over six times the average flow, there are five claims which assert a right to the entire stream. Here we have a little stream whose average flow is about 1,000 inches filed upon to the extent of thirteen times its normal discharge. On Lyman Creek, the source of the city water supply of Bozeman, there are six claimants, each of whom has a recorded claim to the entire stream. On Bozeman, Bridger, Ross, Reese, and other important creeks the condition which exists is almost identical.

In 1905 a law was enacted providing for a further addition to the water-right records of the State. A person having filed a notice as required by law may, when his works are completed, file for record a map and statement showing the completed work, made and sworn to by a competent engineer. This law does not do away with the necessity of a court proceeding for the defining of rights, but it provides a means whereby an appropriator may make a public record of the essential facts as to his right—the location and capacity of his ditch, and the location and area of his irrigated lands as determined by surveys. The law is not mandatory, and will not make the record complete, but if an appropriator files a claim stating what he intends to do, and after completing his works files a map and statement according to law the evidence necessary for a proper defining of his right will always be at hand.

At the same time that provision was made for recording rights, it was provided that in any action regarding water rights all parties claiming rights to water from the same source might be made parties to the action, and all rights be determined in the one action.

WATER RIGHTS ON MIDDLE CREEK.

During the summer of 1864, John J. Chambers and Robert Gillespie settled on unsurveyed lands near the banks of Middle Creek about 6 miles west of the town of Bozeman. In the fall of 1864 these settlers conveyed about 100 miner's inches of water to land through two ditches dug to tap the waters of Middle Creek. In the years 1864 to 1869, inclusive, additional tracts of land were preempted, or homesteaded, by new settlers, each of whom either constructed his own ditch from Middle Creek or acquired an interest in his neighbor's ditch. These first settlers, to the number of thirteen, diverted streams at various points along the lower 9 miles of this creek and were subsequently known in the litigation which ensued as the Lower Middle Creek appropriators.

Lands had been acquired prior to 1870 in the vicinity of the upper part of Middle Creek, but no diversions had been made from this section of the stream. This delay is readily accounted for. The best agricultural lands were situated 1 or more miles from the channel of the stream; the cost of building ditches, owing to the high banks and the long distances, would be considerable, and, lastly, the lower irrigators, having acquired prior rights to the waters of the same stream, might contest the water rights of the upper settlers. To overcome the physical difficulties in the way of obtaining water for their land, and to procure greater financial strength in the prospective litigation with the lower Middle Creek irrigators, the settlers on the upper part of the stream formed themselves into an association, called the Upper Middle Creek Company. This was the first cooperative effort on the part of Middle Creek water users.

For the purpose of avoiding a conflict, this association began to negotiate with the farmers on the lower part of the stream. This resulted in the fall of 1871 in a contract which provided for an exchange of water. The Upper Middle Creek Company conceded to the lower users their prior rights to the waters of the creek, to the extent of the capacities of their several ditches, and agreed to construct and maintain a canal to convey water from the West Gallatin River to the channel of Middle Creek above the head gates of the lower users in quantities to equal if not to exceed the aggregate capacity of the lower ditches. The upper irrigators reasoned that if their association was willing to bear all the expenses in conveying water from a source which had an abundant surplus to the channel of Middle Creek they would then be entitled to divert from Middle Creek at higher points a volume of water equal to that which was to be conveyed from the West Gallatin River.

Several stipulations were inserted in this contract to protect the lower Middle Creek appropriators, the chief of which were that the upper company should acquire no rights to the use of said water until the supply ditch was built and furnishing water, and that the rights granted by the contract should be suspended if the quantity of water furnished through the supply ditch should be less than the aggregate of the quantities of water then taken out of Middle Creek by the lower appropriators.

In consideration of these stipulations the lower appropriators, citing the words of the contract, "do hereby give and grant unto the said members of the said ditch company and to their heirs and assigns our rights respectively to the use of the water naturally flowing in Middle Creek to the extent and capacity of said supply ditch of said company and the waters actually supplied by it into Middle Creek."

This contract was signed by nearly all of the lower appropriators, but never was acknowledged or recorded in the records of Gallatin County.

In pursuance of the contract the company completed the main portion of its ditch from Middle Creek and also the supply ditch from the West Gallatin River. The latter was begun in March and completed June 9, 1872. It was 12 feet wide on the bottom, with varying depths and grade, and was intended to carry 3,000 miner's inches. The contractors were paid by cash assessments levied on members of the association.

Middle Creek ditch was also built by the members of the same association. Instead, however, of levying an assessment payable in cash, each stockholder was required to provide a certain number of men and ox teams, and to perform an amount of work proportionate to his interest in the new canal. At that time one share entitled the owner to the use of 100 miner's inches.

For ten years after the building of Middle Creek canal there were disputes over water rights, but no court proceedings were instituted until the spring of 1883. During this interval a third disturbing element had been introduced in the form of thirty or more new appropriators, who had settled on lands above the Middle Creek canal and diverted water from the upper part of Middle Creek. The rights of these latest claimants, with one or two exceptions, were of later date than those of the lower Middle Creek appropriators and the Middle Creek Ditch Company, but their position on the stream gave them decided advantages.

In April, 1883, John M. Robinson and the lower appropriators to the number of twenty-one entered suit against Charles E. Hoy and thirty-eight other appropriators who had diverted water from the upper part of Middle Creek. At this time the lower irrigators had just cause to seek redress. The Upper Middle Creek Company had failed to comply with the terms of the contract signed in 1871, in that they neglected to maintain and operate the supply ditch from the West Gallatin River. This neglect on their part was trivial when compared with the damage inflicted on the plaintiffs by the new settlers, who, through their numerous ditches near the mouth of Middle Creek canyon, had diverted the greater part of the flow of the stream, causing it to become dry at times above the mouth of the supply ditch.

A decision was rendered by Judge Wade in October, 1883, in which he decreed 2,415 miner's inches to the twenty-two plaintiffs and 445 miner's inches to the thirty-nine defendants. Little benefit resulted to any of the interested parties from this suit. It was a futile attempt to adjudicate priorities between a certain number of claimants and to exclude others who had valid rights to the stream, but were neither plaintiffs nor defendants.

The Upper Middle Creek Company was maintained until 1886, when it was changed to a corporation under the name of the Upper Middle Creek Supply Ditch Company. This company was succeeded in January, 1890, by the present Middle Creek Ditch Company.

On July 15, 1890, the contract of 1871 was annulled by the consent of all parties in interest, and a new arrangement was made whereby the supply ditch with its water right was deeded to the lower Middle Creek appropriators by the Middle Creek Ditch Company in exchange for water rights on Middle Creek.

In 1889–90 the Middle Creek Ditch Company renewed the contest against the upper irrigators which was begun by John M. Robinson and his associates in 1883. This suit was known as the Middle Creek Ditch Company *v.* John J. Henry et al. There were in all twenty-two defendants, who had settled on bench lands near the mouth of the canyon, and had diverted water from Middle Creek for irrigation purposes for the most part subsequent to 1870.

More than two years elapsed between the time of issuing a writ of injunction against the defendants and the beginning of the trial. On July 9, 1889, the defendants were restrained from interfering with the waters of Middle Creek and on November 27, 1891, the trial began. There were so many witnesses to examine that the case occupied the time of the court for a period of twenty-three days.

April 22, 1892, the court rendered a decision, holding that when the lower claimants entered into the contract of 1871 for a consideration they abandoned all right and interest in the natural flow of Middle Creek. This ruling was extremely adverse to the Middle Creek Ditch Company, inasmuch as it changed the date of appropriation of nearly one-half of the flow of its canal from the years 1864, 1865, 1866, and 1867 to a time subsequent to 1871. The plaintiff company then moved for a new trial, and the motion being denied the case was appealed to the supreme court of the State. By a decision rendered April 1, 1895, the supreme court reversed the ruling of the lower court in excluding certain evidence and remanded the case for a new trial.

So, after nearly six years of litigation the litigants began to realize that little had been done toward a final settlement of their claims to water. The long-continued contest had converted former friends into enemies, the uncertainty in regard to the use of water had diminished the products of their fields, and the unusually heavy cash assessments that were levied annually to maintain their actions in court had deprived them of needed comforts at home. The demand for peace finally prevailed and a compromise was effected.

On August 15, 1896, an agreement was entered into regarding the dates of appropriation and the corresponding quantities of water which should be allotted to each legal claimant. This agreement, with the consent of all parties interested, was afterwards embodied in a decree rendered by Judge Henry, of the ninth judicial district, on March 11, 1897. The following is a summary of Judge Henry's decision:

> It is ordered that the plaintiff, the Middle Creek Ditch Company, is entitled to use and to the use, control, disposal, benefit, distribution, and enjoyment of 2,900 inches, statutory measurement (72.5 second-feet), of the waters of Middle Creek, according to the respective dates of appropriation thereof, and in the quantities of the said appropriations as follows:

Date of appropriation.	Name of appropriator.	Statutory inches.[a]	Remarks.
1864	Robert Gillespie	100	The first 13 appropriators herein given were known as the "Lower Middle Creek appropriators."
1864	John J. Chambers	100	
1865	Chris. M. Waterman	100	
1865	Horace Salter	100	
1865	Calvin Jewett	100	
1865	John McCormick	100	
1866	Elbert E. Robinson	100	
1866	John M. Robinson	100	
1866	Eliza B. Sanford	100	
1866	George Austin	100	
1867	Aaron T. Ford	100	
1867	James McCormick	100	
1869	Moses W. Goodall	100	
		1,300	
1866	Henry Monforten	100	
1870	John Kittle	100	
1871		100	Through Ray and Eckley ditch.
1871		100	Cline, Ferguson, and Baxter ditch.
1872		125	Mitchell, Cleveland, and Baxter ditch.
1872		200	Ray and Eckley ditch.
1873		150	Through Main canal.
1873		100	Cline, Ferguson, and Baxter ditch.
1875		175	Main canal.
1877		100	Do.
1879		75	Ray and Eckley ditch.
1880		100	Mitchell, Cleveland, and Baxter ditch.
1881		175	Cleveland, Ferguson, and Baxter ditch.
		1,600	

[a] 100 Montana statutory inches are equivalent to 2.5 second-feet.

The later appropriations, known as the Upper Middle Creek appropriations, amounting to 1,600 statutory inches (40 cubic feet per second), together with the former 1,300 statutory inches (32.5 cubic feet per second), make up the 2,900 inches, or 72.5 cubic feet per second, decreed to the plaintiffs.

To John J. Henry and his associates to the number of twenty-two, who were the defendants in the case, were decreed the following quantities:

Date of appropriation.	Name of appropriator.	Statutory inches.
June, 1866	John J. Henry and Edwin Hodgman	50
July, 1866	Henry Monforten	100
July, 1868	John J. Henry and Henry Hodgman	100
June, 1869	Randolph W. Brooks	100
October, 1869	White Caldwell	100
Do	Joseph Plumb	100
June, 1870	William Welch	100
April, 1872	do	100
June, 1872	William Kent	75
July, 1873	Henry Monforten	100
July, 1876	S. M. Gowan	100
April, 1877	James White	100
July, 1877	John J. Henry	200
May, 1878	Edwin Hodgman	100
Do	Charles Loverich	120
Do	Joseph McElroy	120
Do	Charles E. Hoy	250
June, 1878	Joseph McReynolds	100
Do	John D. Huffine	100
April, 1881	Charles Holmes (administrator)	125
July, 1881	Randolph W. Brooks	100
May, 1882	Charles E. Hoy	100
July, 1882	Henry Monforten	100
		2,540

The water rights of John J. Henry and Henry Hodgman, which date back to 1866 and include 150 inches (3.75 cubic feet per second in the decision), formed the old Penwell right, and the court permitted Henry and Hodgman to change the place of diversion from Lower Middle Creek to one near the mouth of the canyon.

Comment on the foregoing statement of facts seems unnecessary. It tells the familiar story of heroic efforts to subdue the desert and maintain at the same time an action in court over a contested water right.

From 1891 to 1895, inclusive, a period of five years, the Middle Creek Ditch Company levied in cash assessments $5,259.50. The disbursements of this sum are grouped under the following heads:

For services of attorney	$3,160.00
For court fees	999.30
For canal maintenance and repairs	737.20
For miscellaneous expenses	363.00
Total	5,259.50

The expenses in court fees are low, because the Middle Creek Ditch Company won the suit and the other litigants paid the greater part of the costs. The writer has no opportunity to ascertain accurately the aggregate cost to all the litigants. It is safe to say that if all the losses in time and money incurred by the irrigators of this stream in defending their rights to water were reckoned, the sum would reach $13,000.

The aggregate quantity of water decreed is 136 cubic feet per second. Assuming the present commercial value of a cubic foot per second, or 40 Montana statutory inches, in Middle Creek to be $300, the total value of the water adjudicated would be $40,800; that is to say, it has cost nearly one-third what the water is worth to obtain a judgment, and this judgment is of little practical benefit to the irrigators, because there is not a single measuring device on any of the ditches by means of which an appropriation can be measured, and in consequence the distribution is only guesswork, just as it was before a decree was rendered.

WATER RIGHTS ON WEST GALLATIN RIVER.

In the years 1864 and 1865, simultaneously with the early settlement on Middle Creek, the waters of the West Gallatin River were first used in the irrigation of the bottom lands along the lower reaches of the river. The greater number of these earlier ditches were individual or small cooperative enterprises. Between 1865 and 1880 the irrigated area increased steadily and to such an extent that greater effort was required than could be put forth by the small cooperative organizations; and at this time and during the succeeding eight or ten years the larger cooperative and canal organizations and incorporated companies came into existence and began the rapid extension of canals to the higher lands. Since 1890 a few new ditches have been constructed, but development has been chiefly along the line of extension of the older ditches.

The development of irrigation on this stream has been punctuated with many minor quarrels over water rights, but these for the most part have been on a small scale. The only case which has reached the courts and which has involved any considerable number of interests was a suit instituted in the district court in the spring of 1892. The suit was brought by T. J. Lynde, owner of considerable land near Salesville and also of a sawmill, which derived its power from the river at that point, against a great number of the older appropriators on the river. The suit was brought by stipulation for the purpose of legally defining the rights of the litigants and making the procedure a matter of record. In his complaint the plaintiff set forth as his chief cause for action that his was an old right to water, having been acquired by appropriation in 1868, and that in course of a few years the witnesses by whom he could establish his right to water would in all human probability die and he would then be unable to prove or establish this just right. In closing his complaint he took advantage of that section of the irrigation law providing that he might make all the appropriators from the same source defendants.

Such testimony as was taken in the trial of the case was of a superficial nature and little or no effort was made to verify the amounts of water claimed or the dates of first use as submitted by the defendants in their respective answers. By stipulation and agreement the defendants consented to the decree which gave to each party to the action, plaintiff and defendants alike, the amount of water claimed.

Owing, however, to the motives which prompted those interested in bringing suit and to the loose way in which the rights of the various parties to the action were determined, the decree fell into disrepute, and so far as the West Gallatin irrigators at the present time are concerned the action might as well have not been instituted. A law passed in 1905, making decrees "based upon evidence introduced and not upon stipulations or admissions of the parties" prima facie evidence of the facts therein contained, implies that the decree is equally valueless as a record to be used in defining rights in the future.

Up to within the last three or four years the river's supply has been adequate; but owing to an increased use of water and to one or two years of short water supply since, such as those of 1900 and 1901, the question of water rights has become a live issue and one which is causing a good deal of discussion among all appropriators, regardless of the size of their holdings.

During the season of 1900 the water supply was considerably less than in former years, and toward the lower end of the river the shortage was keenly felt. This shortage at the lower end was not due entirely to the decreased flow of the river, but was due to the lack of stream control, for had its flow been equitably distributed every one would have had sufficient for his needs. The ditches and canals higher up on the river diverted their usual amounts of water with the result that those on the lower reaches were forced to do with a short supply. This condition led to the organization of the Farmers' Defense Association by the appropriators on the lower reaches of the river.

This organization, as at first outlined, was to include only those whose rights dated prior to that of the West Gallatin Irrigation Company. Its object was to institute civil action against this company and all those holding subsequent rights and thus bring about a court adjudication of the various interests. The movement, however, was not generally popular and for the first year failed of its object. The following year, 1901, the water supply was still shorter than that of the previous year and early in the spring the organization was revived. It soon became apparent that unless the shortage was relieved by some means serious results would follow. During July the association sent a committee to interview the larger canal interests with a view to inducing them to decrease the amount of water they were diverting, so that the supply in the lower section of the river might be somewhat increased. The efforts of the committee met with success, and with this assistance the lower irrigators were enabled to get through the season. The generous action of the large companies had the effect of bringing all the irrigators on the river into a closer understanding, with the result that the original purpose of the association was abandoned and a reorganization affected. The association as reorganized was made to include all those who wished an amicable settlement of water rights. The idea, however, of resorting to the courts was still retained and although the membership of the association comprised only a small proportion of the West Gallatin irrigators, it nevertheless intended, if possible, to bring the question to an issue. Several law firms were interviewed by committees for the purpose of ascertaining the probable cost of the intended litigation. The terms of one firm were unique and present something new in the line of water-right protection; they offered to take the case for $40 per 100 inches of water obtained for each defendant. Nothing resulted, however, from the actions of the association, for as the season was drawing to a close and the farmers began to hope for a better supply the coming season, their desire to carry the question into the courts was lost sight of.

With the opening of the season of 1902 an attempt was made to again revive the organization, but there was prospect of a good water supply, and the whole matter of bringing about any concerted action was given up.

The association was instrumental in bringing relief to the lower irrigators in 1900 and 1901, and their efforts along this line were well timed and in the right direction, but it can not be admitted that their desire to precipitate a lawsuit over water rights was well advised. The entire absence of any reliable and trustworthy data or records regarding the various rights either as to the amount used or as to the date of appropriation would make hasty litigation just at the present time most disastrous.

What the irrigators of this section do not now possess and what is absolutely essential to an equitable and final adjudication of the stream may be enumerated under the following heads:

(1) Reliable data relative to the early use of water from each ditch and the subsequent enlargement and extension of the same.

(2) Trustworthy measurements of the flow of the West Gallatin River at various points along its course.

(3) An accurate determination of the capacities of all ditches and canals on the river.

(4) Accurate and simple means of measuring the flow in each ditch and canal, preferably a good rating flume or weir.

(5) Data as to the amount of water from each ditch and canal which is put to a beneficial use during an average season.

(6) An accurate survey and description of all lands which have been irrigated from each ditch.

It was with a view to getting such data that the special investigation of water rights and their relation to the use of water from the West

Gallatin was begun. As mentioned in another part of this report, the investigation included a series of measurements of the various ditches and canals diverting water from the river. In addition to the data thus obtained, a careful study of all existing water rights was made. This water-right study included not only those rights of which a record has been made, but also those of which there is no record and which depend entirely for their validity upon actual appropriation and use. The material thus gathered has been brought together in the following tables, one of which deals with canals on the east side of the river, beginning with the highest, while the other takes up the canals on the west side in a similar manner.

In the two columns under the head of "Date of appropriation" are given the recorded and claimed dates of appropriation. One column contains all rights which have been recorded, while the other contains the dates of appropriation claimed by those whose rights have not been recorded. The figures in the column of "mean flow" are derived from tables given in another part of this report (see p. 20), and are inserted in these tables for the purpose of showing the wide discrepancy between the amounts claimed and the amounts actually diverted.

West Gallatin River canals.

WEST SIDE OF RIVER.

Name of canal or ditch.	Date of appropriation.		Amount claimed.	Mean flow, 1902.	Acreage served.
	Recorded.	Claimed.			
			Inches.	*Inches.*	
Williams, No. 1	Aug. 15-18, 1886		400	160	320
Williams, No. 2 (lower)		1882	250	606	
Cockrill		1881	750	118	
Todd		1867	200	60	
West Gallatin (high line)	Aug. 7-18, 1889 May 9, 1890		50,000 50,000	3,669	
Sterling	July 7, 1883		1,000	254	160
Le Beau	1865-66		1,557	465	1,557
Railey	May 15, 1890		440	88	360
Gabriel	1866[a]		400	94	80
West Gallatin (short line)				869	
Kughen or Cameron	Aug. 25, 1882		3,600	2,421	2,943
Cameron, Nieble, Corrie & Clark		1875-76		555	1,500
Corrie		1880	200	35	100
Davidson, Leach, Smith & Heiskell	Aug. 26, 1882		2,000	1,136	1,895
Lewis	1865		7,750	779	2,395
Holgate & Grove	Mar. 26, 1889		1,000	502	320
Manhattan or Moreland	Oct. 5, 1889		3,000	744	5,440
Patterson & Boss	1889		2,000	356	680
White or Cayuse	June 12, 1883		3,000	1,008	1,360
Buckley, Curtis & Holgate	May 15, 1892		1,000	342	480
Lamphear & Bryan	May, 1887		300	276	280
Heeb & Kennedy		1865	400	118	
Heeb, No. 1		1872-1888	500	381	
Heeb, No. 2		1868	100		
Cruse, No. 1				138	
Lower Manhattan	1890		2,500	897	2,560
Baker	July 19, 1901		1,000	213	240

[a] Included in high-line appropriation.

West Gallatin River canals—Continued.

EAST SIDE OF RIVER.

Name of canal or ditch.	Date of appropriation.		Amount claimed.	Mean flow, 1902.	Acreage served.
	Recorded.	Claimed.			
			Inches.	*Inches.*	
Kleinschmidt				3,841	
Bush				396	
Ralph		1883	250	88	
Farmers, or Excelsior	Sept. 29, 1890.		5,000	6,716	
Ferris				712	
Middle Creek Supply		1872	3,000	1,864	
Accola		1870	(a)	200	
Beck, Border, Spring & Matthews	Aug. 9, 1894		2,100	792	2,000
Tudor & Nieble		1865-66 1885	350 120	165	280 120
Spain	Oct. 30, 1886		1,200	1,027	4,840
Waterman	Feb. 20, 1890 1866		3,000 2,600	200	
Ketterer, Owenhouse & Stephens	July 4, 1882 Apr. 12, 1883 May 1, 1887 June 1, 1898 Dec. 20, 1899		600 200 1,500 300 [b]220	1,107	1,000
Knadler & Foerschler	June 28, 1887		900	465	600
Stephens & Creasy	June 10, 1888		400	433	320
Weaver & McDonald	Mar. 12, 1887		1,200	495	1,620
Knadler, White & Knadler		1886	200	32	30
Hoffman, Stephens & Cook	Mar. 1, 1887		1,200	437	800
Weaver & Stone	Aug., 1881		1,000	132	480
Learmouth, Ferguson, Owenhouse & Patterson	June 1, 1892 May 13, 1901		900 [b]30	348	1,360
Hoffman & Marks	May 15, 1889		600	278	430
Bell, Franks & Creasy	May 20, 1887		1,000	224	900
Old Creamery ditch		1865	(c)	262	720
Dawes Bros. & Porter	July 14, 1882		(d)	245	380
Gibson & Green	Oct. 17, 1865		(c)	20	320

[a] All ditch will carry. [b] Cubic feet per second. [c] Not given. [d] All ditch takes.

As shown above, for only about two-thirds of the bona fide diversions from the West Gallatin River are claims recorded. On this subject of recording claims various irrigators expressed themselves. Those holding early rights which were not recorded made the statement that they felt that under the present law little was to be gained by recording their rights, and so long as it made no difference as to getting their water why should they go to the expense of recording when guaranteed no protection or benefit? On the other hand, those whose rights had been placed on record were prompted to the action on the principle that what would do no harm might some day do some good.

The season of 1902, differing from those of the two years previous, was one of abundant water supply. Even the irrigators generally admitted that there was no cause for complaint, and said that all were drawing more water than they actually needed, yet despite this fact the figures in the table show that there were only four out of the whole fifty-one ditches whose average flow for the season in any way equaled or exceeded the amount claimed for them, while the greater majority drew only a fraction of the amount claimed. Right here will be encountered the great difficulty when it comes to the final adjudication of the rights to the stream's flow. Irrigators who have set up a claim to a certain amount of water for years, probably not realizing in most instances the wide variation between the amount they use and the amount they claim, will, when the test comes, be loath to accept a smaller right, although it may be conclusively proved that they need no more.

APPLICATION OF WATER TO CROPS.

PREPARING THE LAND.

In Montana large expenditures have been made in building canals, but the skill which has been exercised in conveying water has not been extended to its proper application to the soil. This is usually attributed to the fact that irrigation has not been long practiced in Montana, and the time of the agricultural classes has been occupied mainly with the diversion and conveyance of water, leaving them little time to put their fields in proper condition to receive water. This is true of many of the new districts. The settler who is striving to make a home in an arid country on a small amount of capital can not well afford to spend $10 per acre for a water right and an additional $10 per acre in leveling, grading, and ditching his land. There is no valid excuse, however, for the people of the older-irrigated section continuing the use of the crude systems of pioneer days.

The methods of preparing land for irrigation in Montana do not differ materially in even widely separated sections. There is less tall sagebrush than in Utah or Idaho, and there is a larger and more uniform growth of native grasses. In old irrigated sections, like Gallatin Valley, there is little unbroken land under the ditches. The usual preparation is therefore confined to the surface of fields which have been cultivated and sown to crops for many years. Gang plows, disk plows, sulky plows, and the ordinary walking plows are all more or less used. In the work care is taken to leave the surface as level as possible after the plow and to avoid the making of dead furrows. If the surface is rough a disk barrow is used to break up the lumps. It is leveled and smoothed with one of the many kinds of home-made levelers, or with one of the patent levelers now on the market, and afterwards the seed is drilled in some 3 inches deep.

A method of preparing new land, somewhat novel in Montana, has of late been introduced in Beaverhead County. Much of the irrigable land of this county is comparatively smooth and level and covered with low sagebrush and rabbit brush. A supply ditch is first dug across the upper end of the field to be plowed and smaller ditches are run down the steepest slopes from the supply ditch. By means of these supply and lateral ditches the new land is thoroughly irrigated, and when the top layer of soil has sufficiently dried out to pulverize freely it is plowed, disked, and leveled. The method is described by J. E. Morse, of Dillon, Mont., as follows:

We begin irrigating as early as May 10, and thus get the use of the high water in the spring when it is abundant. Water is again used for this purpose during the fall months when it is not needed for regular crops. The land is broken up with 3-gang plows drawn by 8 horses. An outfit of this kind will average about 7 acres per day. Soon after plowing the corners of the field and the dead furrows are thoroughly disked. A leveler 24 feet long, made of square timbers and drawn by 6 or 8 horses, is then drawn diagonally with the way the land was plowed. The field is again disked, in part at least, and the homemade leveler is dragged diagonally across the field for a second time, but in a different direction from the first time. This second leveling will generally put the ground in first-class condition for seeding. The field lies in a state of rest or summer fallow until the following spring, when it is seeded to oats. This work can usually be commenced in March or whenever the frost is out of the ground and the soil is thoroughly dry on top. We use a disk drill, and with 4 horses can seed from 16 to 20 acres a day. The amount of seed varies from 85 pounds, when sown during the first half of April, to 100 pounds when sown in May.

In some other parts of the State where irrigation is practiced the original surface is uneven, containing what is known as buffalo wallows. It is both difficult and costly to prepare such land for irrigation, the cost being sometimes over $10 per acre. The process of leveling involves the shifting of considerable quantities of earth. The grading, however, can not be successfully done on fresh sod, and the usual practice of preparing land of this character is to raise first a crop of wheat without water and when the sod is well decomposed and pulverized the grading can be done more cheaply and effectively. The removal of the top layer of soil from the high places in a field and its deposition in low places are also serious drawbacks, since the yield is much reduced on what was originally the edges of the wallows. Summer fallow and the action of frost, rain, and sunshine seem to be the common remedies for these spots. A heavy coating of manure is also beneficial.

Perhaps the most common mistake to be found in supply ditches is the steep grades on which many of them are built. In pioneer days water was conducted along plow furrows running down the steepest slope. A channel of this kind, although small at first, was gradually increased by erosion until it finally became in the majority of cases a wide, deep chasm. These unsightly channels detract from the appearance and value of a farm, and cause the waste of much water through seepage. The most obvious remedy is to change the location; but this can not be easily done, for the reason that the rights of way for such water courses have become vested in one or more owners, and the location can not be changed to one of less grade without an abandonment of the old and the purchase of the new right of way. In such cases, and for volumes not exceeding 200 miner's inches, the writer has recommended the use of tile pipes laid at least 1 foot below the surface, in order to permit the surface to be cultivated. The value of the crops that can be raised on the land occupied by such ditches will in a short time pay for the tile pipe. Other possible remedies are a change of location or the paving of the channel.

Again, it not infrequently happens that the supply ditch first built fails to furnish water to the whole of the farm. This may be due to its small size or its location too low to cover the higher ground. The remedy, always costly, is to build a second feed ditch and either abandon the first or operate and maintain both.

Still another mistake which is common to this and other States is the location of ditches without any regard to drainage. Water is frequently forced from a lower to a higher point along the border of a field by the construction of levees which interfere with and tend to choke the natural water courses. The consequences are a water-logged soil, the rise of alkali, and unprofitable yields.

FARM LATERALS.

These small ditches receive water from the supply ditch and distribute it over the surface. On grain fields the field laterals are run after the crop is seeded and usually when it is a few inches above the ground. In the majority of cases these furrows are run by eye from the bordering ditch at varying intervals. Regarding the direction of the furrows there are two well-defined methods practiced in the State. In one the laterals are located either on straight lines and extend more or less diagonally across the field. In the other the head ditch is located across the upper end of the field and the laterals are run at right angles from it down the steepest slope. When the surface of the ground is smooth and level and the laterals carefully run on a grade of 0.5 to 0.75 inch to the rod the first is preferable. Sometimes large quantities of fine sand or other material are carried down the supply ditch and choke up the small field ditches on slight grades. In cases of this kind the lateral on a steep grade preserves a clear channel and the sand is flushed out on the surface of the field. The distance between field laterals varies from about 70 feet in grain to 100 feet in hay fields. A 14 or 16 inch lister plow attached to a sulky frame and drawn by three horses is the implement most commonly used to make laterals. The furrows are cleaned out by a large shovel plow called a "dammer," which deposits a pile of earth in the laterals at intervals of 40 to 100 feet, depending on the grade.

Objections are made to the presence of so many laterals, in a grain field in particular. At first thought it would seem that the occupying of space by laterals lessens the yield to the extent of the surface not under crop. In accordance with this mistaken idea some men space the laterals far apart in order to effect a saving. As a matter of fact nothing is gained by a wide space of 150 feet between the laterals, for the head of water ordinarily used can not be spread evenly over so wide a belt. The result is uneven distribution and consequent loss of crops. Careful observation shows likewise that the yield is seldom much lessened by the presence of laterals for the following reasons: They increase the circulation of air and the amount of sunshine in a field bearing a medium or heavy crop, and they increase the yield along the lower edge of the lateral by subirrigation from the bed of the channel and by furnishing a top dressing of soil to nearby plants.

The cost of leveling fields that have been cultivated for a number of years and making the laterals varies from 10 to 75 cents an acre, depending on the character of the soil and the degree of thoroughness with which the work is done. A brief description of the methods adopted and the average cost of such work from a few of the most successful irrigators of Montana are herewith given:

Cost of preparing land for irrigation.

Description of methods used.	Cost per acre.	Name and address.
Land leveled, ditches made, and manure dams put in (first year, 50 cents).	$0.20	F. L. Benepe, Bozeman.
Land thoroughly leveled, laterals made with lister, and dams made.	.75	P. Bergland, Manhattan.
Land gone over with 4-horse leveler, and laterals made with disk plow.	.20	J. A. Lovely, Livingston.
Land leveled, laterals made with ditch plow, and earth and manure dams put in.	.75	G. M. Fuller, Bozeman.
Land leveled, laterals made, and dams put in	.50	H. Monforten, Bozeman.
Head ditches plowed after sowing, and dams made with dammer.	.25	E. C. Kinney, Bozeman.
Laterals made with 16-inch lister, and dams made with dammer.	.55	William Frank, Belgrade.
After cropping field leveled and laid off in lands about 15 yards wide by running lateral ditches that far apart, laterals made by throwing a furrow each way and running a wedge-shaped opener through them.	.08	J. E. Kanouse, Townsend.
Main ditch plowed and dirt pushed out with scraper, laterals made with lister, and manure dams put in.	.10	John Holliday, Livingston.
Furrows plowed 60 feet apart and furrows cleaned and dams made at same time with dammer.	.05	W. H. Sales, Salesville.
Laterals made 6 or 7 inches deep with 16-inch lister, and dams made with dammer.	.75	W. R. Bell, Central Park.
Land leveled, and laterals made by throwing a furrow each way and running a crowder through the ditch.	.25	P. Kircher, Clyde Park.

CHECKS IN LATERALS.

Reference has been made to dams of earth made by a dammer. These are confined principally to the grain farms. The most common kind of check for both grain and hay lands is a base of half-rotted straw or coarse stable manure covered over with a thin layer of earth. The manure is distributed in small heaps along the lateral, the space between the heaps varying from 30 to 80 feet, according to the grade. Before irrigation begins it is arranged so as to form a more compact check, and thin coverings of soil are usually placed over the upstream slopes. During the process of irrigating these checks are thrown out on the edge of the bank, leaving the channel free for the passage of water as far as the next check below.

In regions like the Yellowstone Valley, where alfalfa is the principal crop, some form of canvas dam is generally used. Some prefer to use manure for the checks in the smaller laterals and canvas dams for the larger laterals.

In still other districts of the State wooden or steel portable checks are used for the small ditches in the grain fields and canvas dams for the supply ditches.

AN IRRIGATION STREAM.

It is the prevalent opinion among Montana irrigators that one experienced man will handle 100 miner's inches in irrigating grain and a considerably larger stream in irrigating clover, alfalfa, or native meadow land. This head of water, if applied on 6¾ acres, would cover it to a depth of 9 inches in twenty-four hours; or, it would cover 2.75 acres to the same depth in ten hours. It is only in rare cases that irrigators remain in the field at night. The stream is controlled by day, but before quitting time in the evening it is turned on some meadow or hay field to run without attention until morning. The results of such practice are to be seen in a low duty of water, diminished yields, and in time the water logging of soil and the creation of marshes. As land increases in value and as irrigation methods improve, the enormous waste of water caused by permitting an irrigation stream to flow over a field for twelve hours without guidance will be stopped. The division of the present large farms into smaller holdings and the production of a larger variety of crops will tend to introduce important changes in the use of water.

COST OF APPLYING WATER.

The cost of applying water depends on a number of conditions. In the short season of Montana some grain crops are irrigated only once. Other crops, such as alfalfa, clover, and native hay, may be irrigated three and four times. The size of the stream used also makes a difference in the cost, since the acreage watered in a day is usually in direct ratio to the head used. In addition there are to be found all kinds of surfaces. Some have been well prepared, and little difficulty is experienced in spreading water evenly. Others are uneven and poorly graded, with faulty supply ditches.

At the same time some idea of what it costs each season to irrigate a crop is highly desirable, not only for the western farmer, but especially for those who intend to take up farms in irrigated portions of the West. As far as Montana is concerned, it was thought that the most reliable information on this subject might be obtained from the irrigators themselves. Inquiries were addressed to a few of the most prominent of each community, and it was hoped their replies would apply in a general way to the entire community. The figures given in the following statement represent the average of 67 replies received from irrigators in different parts of the State.

Cost of applying water.

Irrigation head used by one irrigator	miner's inches..	163
Number of acres irrigated by one man in one day	acres..	5
Cost of one irrigation	per acre..	$0.44
Cost of season's irrigation	do....	$1.07

An idea of the methods employed may perhaps best be conveyed by a brief description of the irrigation of two staple crops in different parts of the State, viz, a grain crop grown in the Gallatin Valley and an alfalfa crop grown in the Yellowstone Valley.

IRRIGATING BARLEY IN GALLATIN VALLEY.

The land for a crop of barley in the Gallatin Valley is usually plowed in the fall just after harvest and is permitted to lie without further cultivation until the following spring. About the first of May the surface is usually dry and it can then be leveled, harrowed, and seeded. In that section the average rainfall for the two months of April and May is nearly 4.5 inches, enough for the needs of the plant until it is 5 to 7 inches above the ground. The barley crop reaches this stage the latter part of June and is then ready for the first irrigation. Assuming that the head ditch is already constructed and properly cleaned out, the first thing to be done is to mark out the laterals and furrow them out with a ditch plow. The marking out is often omitted, but when done the grade allowed in fields that have been carefully leveled is about 0.5 inch to the rod or, when a 100-foot chain is used, 0.2 foot to 100 feet. The laterals are spaced 60 to 80 feet apart, although the narrower space is to be preferred. Each one connects with the head ditch and is terminated about 50 feet from the lower border of the field. A dammer drawn by one horse follows the ditch plow and forms the earth checks, which are spaced about 60 feet apart. Canvas dams provide the most convenient check for the head ditch. By their use a stream of 75 to 125 miner's inches is divided between two neighboring laterals and the small areas lying between the supply ditch and the first checks are irrigated. The checks of earth are then broken with a long-handled shovel and the water flows in each lateral until it encounters the next check, where it is held until the next space is irrigated. In this way each of the strips lying immediately below each lateral is watered. A thorough irrigation consists in saturating the soil to a depth of 1 foot. In some seasons one irrigation will suffice. In dry years two waterings usually produce the largest yields. Sometimes the second irrigation is light, only part of the full supply required to saturate the soil being used. A volume of water equal to a depth of 6 inches spread evenly over the surface is usually sufficient, when there is no waste, for one thorough irrigation. When the land is uneven or not properly leveled or when it is broken up by ravines, there is usually considerable waste and it may require 9 to 12 inches in depth over the surface for one irrigation. Seldom more than half the quantity of water is used for a second irrigation. In the Gallatin Valley the first irrigation should be applied early in order to have the soil ready for the second application before the heads become too large and heavy. A heavy irrigation applied three weeks before the grain is cut may prove more injurious than beneficial, as the weak stems in the soft soil are not capable of supporting the heads in an upright position. Several days after the last irrigation the laterals are filled in and leveled in order not to obstruct the reaper. This may be done by the use of a small walking plow and two furrows or by means of a special implement containing two disks, which throw the earth to the center and fill the ditch.

Cost of irrigating a 40-acre barley field.

Leveling, ditching, and checking, at 75 cents per acre	$30.00
Value of water used, at $1 per acre	40.00
Applying sufficient water to mature crops, at 85 cents	34.00
Leveling laterals, at 7 cents per acre	2.80
Total	106.80
Gross returns from barley, 58 bushels, at 50 cents	1,160.00
Net returns	1,053.20

IRRIGATING ALFALFA IN YELLOWSTONE VALLEY.

Alfalfa being a perennial plant, the annual cost of plowing, cultivating, and seeding is saved. There is, however, more urgent need for thorough preparation at the time the crop is put in, since an uneven surface or badly located ditches may materially diminish the yields of every crop for a long period of years. The loss, from any one of these causes, of 100 pounds of alfalfa to the acre at each of three cuttings would amount to $9 per acre in twelve years, but such causes frequently reduce the yield to the extent of half a ton per acre, when the loss in the time named would amount to $108 per acre or about double the present value of alfalfa land.

In preparing a field for alfalfa it is better to plow it in the fall. It is then evenly graded and cultivated in the following spring as early as the ground is sufficiently dry to work and the seed drilled in to a depth of about 3 inches. The quantity of seed sown in the Yellowstone Valley averages about 22 pounds per acre. Many prefer to plow the laterals before seeding and to run the seeder as close as possible to the edge of the ditch. This prevents, for a time at least, the growth of alfalfa in the ditches.

Young plants are tender at first and require moist soil for a seed bed until the roots strike into subsoil that is continually moist. They are also liable to be choked by weeds. This can best be prevented by running a mower over the field with the knife set high. By this process the weeds are cut and make mulch, which prevents the soil from baking. The tops of the spindling alfalfa stems are likewise cut, which causes it to stool out and thicken.

In alfalfa fields the laterals should be located with an engineer's level or by some good substitute. The grade may vary from 0.2 to 0.3 foot per 100 feet, and the laterals may be spaced 75 to 125 feet apart. For a permanent crop of this character it also pays to construct wooden checks and division boxes in the supply ditches. When it is found necessary to divide an irrigation stream into two or three smaller heads a division box is convenient. The cost of a box of this kind is

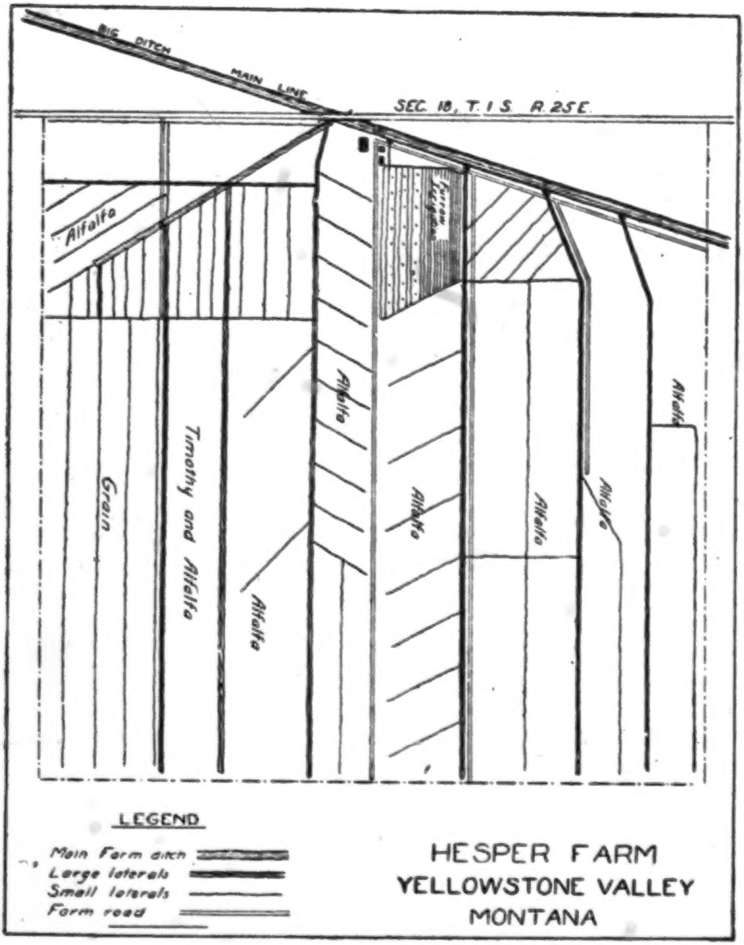
BIG DITCH
MAIN LINE
SEC. 18, T. 1 S. R. 25 E.
Alfalfa
Furrow Irrigation
Grain
Timothy and Alfalfa
Alfalfa
Alfalfa
Alfalfa
Alfalfa
Alfalfa
Alfalfa
LEGEND
Main Farm ditch
Large laterals
Small laterals
Farm road
HESPER FARM
YELLOWSTONE VALLEY
MONTANA

FIG. 5.—Alfalfa field, showing location of laterals.

often refunded the first season in the lessening of the labor bill. By the use of a box of this kind a stream may be divided into three parts, in proportions to suit the convenience of the user, or it may be diverted from one course or lateral into another running in a different direction.

Old alfalfa fields in Yellowstone County are irrigated one to four times during the period of growth. Three crops are obtained from the same field in one season, and as a rule each crop is irrigated. One man handles 80 to 125 miner's inches. The laterals are somewhat larger than those found in grain fields and the water is checked by canvas dams. Occasionally one sees a farmer who uses manure for checks, but the large majority use canvas. Water is distributed as in grain fields (fig. 5). The proper time for each irrigation and the proper amount of water to apply are questions that have not been definitely settled. Too little water diminishes the yield and too much injures the soil by bringing up the alkali. Between these two extremes there is usually some middle course which will produce the best results. For the past three years the average amount of water used by the farmers under the Big ditch, in Yellowstone County, has been 41 inches in depth over an area aggregating 18,000 acres. This includes all losses of all kinds, but making a liberal allowance for waste there would remain about 30 inches, or 10 inches in depth for each of three irrigations. As to the proper time to irrigate, the first application should be made before the crop begins to suffer. It is too late when the plants show the effect of drought. As regards the proper time to irrigate the second crop opinions differ, but it is a common practice in Utah to irrigate just after taking off the first crop. The majority claim that on the large farms of the Yellowstone Valley it is not practicable to remove a crop in the forenoon and spread water over the surface the same day. These contend that so much time elapses between the cutting of the alfalfa and the irrigation of the stubble that the latter is badly injured and takes a long time to recover after being watered. Those who hold this view prefer to apply the water before the alfalfa crop is cut, allowing sufficient time for the drying out of the soil before cutting.

Cost of irrigating a 40-acre alfalfa field.

Interest on cost of preparing land, at 50 cents per acre	$20
Repairing and cleaning out laterals, at 25 cents per acre	10
Cost of water used, at $1.50 per acre	60
Cost of irrigating three times, at $1.25 per acre	50
Total	140
Gross receipts from three cuttings, 6 tons at $5 per ton	1,200
Gross receipts, less cost of irrigation, on 40 acres	1,060

DUTY OF WATER IN MONTANA.

Montana is a large State, but the bulk of its agricultural products will always be raised on comparatively small areas, because of the limited water supply. This being true, the duty that can be secured for its water supply will measure to a large degree the future possibilities in agriculture. For this reason the study of the duty of water and the conditions which influence it assume great importance.

If it is desired to reclaim an arid tract of land the engineer must decide not only upon the total quantity required for the season but also the maximum amount to be delivered at any one time. Having decided as to the largest volume of water required for any given period, he designs the canal structures accordingly. If this estimate is too large, a part of the money of the investor will serve no useful purpose. On the other hand, if the estimate is too small, the enterprise will be a partial failure, for there will not be sufficient water to irrigate all the land. Similarly, when water is to be stored to irrigate land, the capacity of the storage reservoir and the cost of the structure are both dependent to a large extent on the service which the stored water will perform when applied to the soil. There is the same necessity for accurate information on this point when a pumping plant is to be installed. Otherwise money will be wasted in the purchase of a plant of too large capacity or else the plant first installed will be too small to raise the requisite amount of water and will have to be replaced by one of greater capacity.

Thus it is evident that from an engineering standpoint a knowledge of the amount of water required for land of a known character and for particular crops is necessary. Such knowledge is all the more important when one considers that about 80 per cent of the irrigable lands of Montana is yet to be reclaimed. Judging from the progress made during the past fifteen years, the extent of land reclaimed in the next fifteen years by private enterprise will amount to 1,750,000 acres. If this area is increased by a third of a million acres of Government land, which it is presumed will be reclaimed by the Federal Government under the operation of the irrigation act passed June 17, 1902, it will increase the amount to over 2,000,000 acres. There is perhaps no question of more vital importance to the future of Montana than a knowledge of the right amount of water to apply, not only to the land which may be irrigated in the next fifteen years, but to all the irrigable lands.

When one considers the broader features of this subject, which pertain to the equitable allotment and distribution of water, its importance is much increased. The basis of all equitable allotments must rest on the amount of water required to properly irrigate land. This question thus becomes one of the main factors in the determination of rights to the use of water. Even after rights have been established, the proper duty of water is still the cause of much dispute between those who regulate, control, and administer the public waters of a stream and the farmers who use the water.

SOME CONDITIONS WHICH AFFECT THE DUTY OF WATER.

The ordinary irrigation channel receives much more water from the stream than it delivers to the irrigated fields. Porous soil and a high summer temperature cause losses in conveyance in the main canals, seldom less than 10 per cent and rising occasionally to over 50 per cent of the total volume diverted. The flow, after it is turned out of the main canal into laterals, is subjected to a still further reduction in volume from the same causes, so that in stating the quantity of water used on a tract of land it is important to locate definitely the place of measurement. When the irrigation stream is measured as it crosses the highest boundary of a field there is practically no loss in conveyance. When, however, the water is measured at the point of diversion from the natural channel, all losses due to seepage, evaporation, and leakage are included, and this shows a much larger quantity used.

Rainfall, midsummer temperatures, and the length of the irrigation period all modify the quantity of water required. In Montana all three conditions are favorable from the standpoint of the economical use of the water supply. The average annual precipitation over the cultivated portions of the State is over 14 inches, and a large part of this occurs in April, May, and June, when farmers need moisture most to start their crops. In the Gallatin Valley in particular the rainfall during these three spring months is fully equal to one irrigation, and forms about 30 per cent of the average amount of water received by fields under careful irrigation. The evaporation is likewise low during the time when water is applied. The average weekly evaporation from a water surface at Bozeman, Mont., for the past four years has been 0.94 inch for the months of May, June, July, and August—much less than it is in the more southerly and warmer portions of the arid region. For the same reason the period during which water can be used is comparatively short. In some parts of the State irrigation water is applied in April and May, but, taken as a whole, the ordinary crops receive the greater part of the season's supply from May 15 to August 15. The average length of the irrigation period in Montana does not exceed one hundred days.

Water can seldom be economically used on a one-crop farm. This is particularly true of the cereals. If one's holding is all planted to wheat, for example, a large flow may be required for a short period, but when the needs of this one crop are supplied the owner may have no further use for the irrigation stream. In growing alfalfa, or any other leguminous crop, under irrigation it is possible to get a higher duty out of the water supply, for the reason that two or three crops may be grown on the same field in one season. A farmer who is entitled to the continuous use of 1 cubic foot per second for 80 acres may thus be able to supply water to three crops of alfalfa at the same cost as to one crop of wheat. In doing this he may use more than three times the amount of water, but, assuming that he pays season rates, the cost would not differ.

It is only, however, on the diversified farm that a continuous stream can be utilized to the fullest extent. When a dozen different crops are grown on an 80-acre farm the proper time to irrigate is seldom the same for any two, and so it is possible to keep a small stream flowing continuously on first one and then another of the subdivisions.

On account of the large size of the average farm and the plentiful supply of water, the necessity for time rotation in the delivery of water has not been keenly felt in Montana up to the present. It is only when a scarcity exists that neighbors arrange to use in turn the supply which belongs to, say, three proprietors. In this way each of three farms can secure an effective irrigation head for one out of every three days. As water becomes scarce and of higher value and as the farms become reduced in size this method of delivering water will gradually ~~become~~ more common.

The subsoils of western lands when first brought under irrigation contain little moisture. The most striking characteristics of these formations are their great depths and the close similarity which exists between the surface and subsurface layers. Apart from their darker color, due to decayed vegetable matter, there is little to distinguish top soils from bottom soils, and the roots of plants extend to great depth through the latter. On account of these prevailing physical features a large part of the water which is applied for the first few seasons is absorbed. Cases are common in which new land has absorbed in one season a quantity of water which would have covered the surface to a depth of 6 feet. To claim that this large volume correctly represents the duty for such land is a misrepresentation, because the open space in the subsoil is gradually filled with water and the ground-water level in time rises nearer the surface. It is a fact, however, that new land requires much more water per acre than old cultivated fields, and crops are likely to suffer if it is not supplied.

Other conditions being similar, less water will be used on a farm which has a good system of ditches and laterals and a well-cultivated even surface. The beginner is not always posted as to the best way to lay out and build farm ditches, and he may not possess sufficient means to properly prepare his fields for irrigation. These defects invariably prove quite costly in the end, when measured in waste of water and small yields. In an arid country thorough cultivation serves a double purpose in that it increases the yield and prevents the escape of water into the atmosphere. Grading or leveling the surface is even more important, since it is difficult to apply water to an uneven surface, the growth of the crop is not uniform, and the soil in the low places is likely to be damaged by an excess of water.

The time necessary to mature plants differs. Under favorable conditions a crop of alfalfa can be grown in less than fifty days, a crop of barley in something over one hundred days, while it may require one hundred and fifty days to ripen certain varieties of fruit. There is not only a difference in the period of growth, but also in the number of crops grown in one season.

The way in which water is applied is perhaps as important as the quantity used. Some soils bake after being flooded and furrow irrigation must be used for all crops. Other soils are so porous that furrow irrigation is not practicable. In irrigation by flooding, as generally practiced in Montana, care is usually taken to distribute the water during the day, but it is left unattended during the night. Fully 20 per cent of the available supply may be wasted while the irrigator sleeps or is off duty.

A part of the Gallatin Valley is underlaid by coarse gravel and cobbles and a large percentage of the water applied to the surface sinks into these porous materials and drains down the valley. Other portions are undulating, which renders the application of water somewhat difficult.

In the Bitter Root Valley much of the fruit soil is light and porous, and is located for the most part on steep slopes. For these reasons the amount of water used is considerably above the average. Along the Milk River Valley the slope is flat and the soil somewhat heavy. These conditions favor a high duty, and when this part of the State is further developed it is expected that a cubic foot per second will be sufficient for 100 acres.

It frequently happens that fields which have received large quantities of water produce low yields. This result may be due to one or more of a large number of causes. Chief in importance is the proper cultivation of the soil. It may be regarded as one of the fundamental truths in agriculture that irrigation can not take the place of cultivation. The western irrigator has been slow to recognize this fact, and is still inclined to depend too much on irrigation and too little on cultivation. As a rule, in Montana the largest and most profitable yields are obtained from the use of a moderate amount of water. The people of Gallatin Valley, who produce the largest yield of grain in the State, use the least amount of water in irrigation.

Throughout the most productive regions of the State sufficient water is diverted to cover the land watered to depths varying from 3 to 5 feet, but since a large percentage is lost in transit the volume which reaches the fields would not cover them to depths greater than 20 to

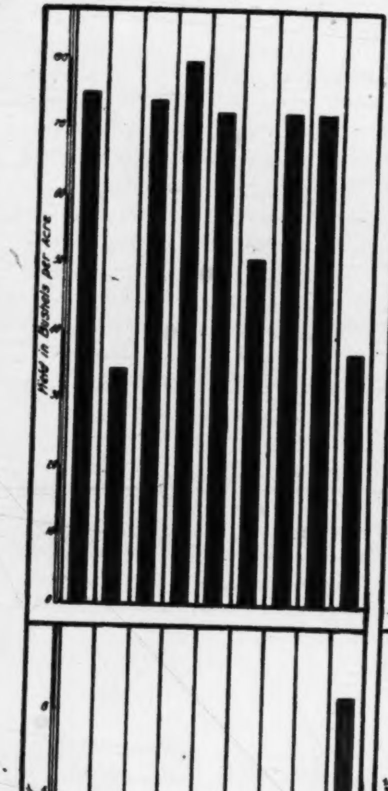

FIG. 6.—Depth of water received by oats, and yields.

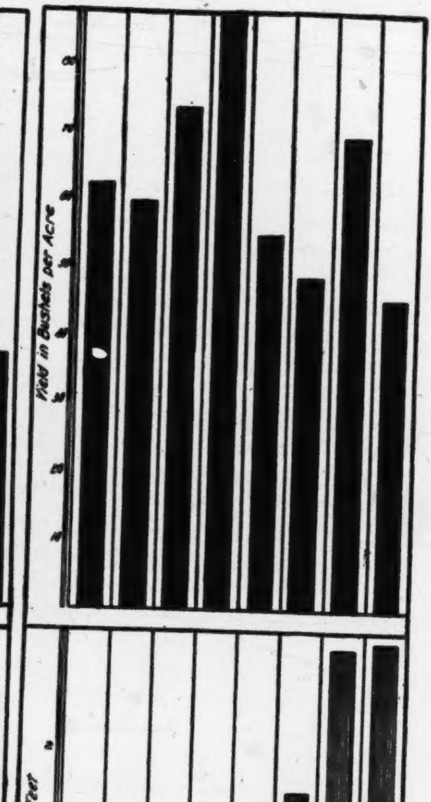

FIG. 7.—Depth of water received by barley, and yields.

40 inches in a season. There are other portions where water is so cheap and plentiful that the owners are careless in its use. They open the head gates and permit a large stream to flow for days at a time without much, if any, attention. Men who use large quantities of water, covering their fields to depths of from 4 to 10 feet every season, are usually the most careless in preparing the land or in cultivating the surface, and the result is without exception a small yield.

That yields do not depend wholly on the amount of water applied is clearly shown by figure 6. This diagram shows the amount of rainfall and irrigation water received by eight oat fields, with the corresponding yields. The lower half of the diagram shows the depth of water received and the upper half the yields on corresponding tracts. A field which received over 6 feet of water in two irrigations produced only 37 bushels per acre, while a field which received in one watering less than 7 inches produced 75.5 bushels. The largest yield was 80½ bushels per acre from a field which received 1.04 feet of irrigation water and 0.64 foot of rain water.

In figure 7 are shown like results on eight fields of barley. There are no large amounts of water used, all being less than 30 inches in depth. Still, the largest yield was not obtained from the use of the most water, which was 1.98 feet of irrigation water and 0.42 foot of rain, or 2.40 in all. A yield of 87.25 bushels was harvested from the field which received less than 18 inches in both rain and ditch water.

The results of six wheat crops shown in figure 8 indicate that the amounts of water used ranged from a small to a medium amount and that the yields varied to some extent with the water applied.

Figure 9 shows yields of clover and the quantities of water applied to nine clover fields. In this crop the largest yield was from the heaviest watering, but, on the other hand, the next largest use of water produced a small crop.

In comparing records of thirty-two irrigated fields, as given in the diagrams, the conditions under which the crops were grown should be considered. It is important to remember that the crops were grown in different seasons, in different parts of the State, and in many cases under a wide diversity of soil and climate. In view of this fact, the records as given should not be used to base conclusions as to the proper amount of water to use in the raising of these staple crops. They do show, however, that when other conditions are favorable it is possible to obtain a large crop with a small amount of water.

UNITS OF MEASUREMENT.

In the measurements of duty of water reported in the subsequent pages several units are employed to state the quantities of water used. The irrigators generally use the term miner's inch, being unfamiliar with the term cubic foot per second. As it is impracticable to

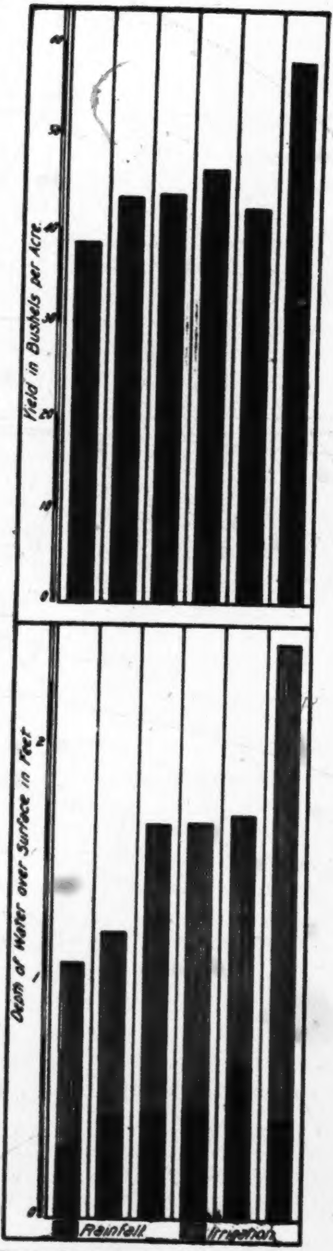

FIG. 8.—Depth of water received by wheat, and yields.

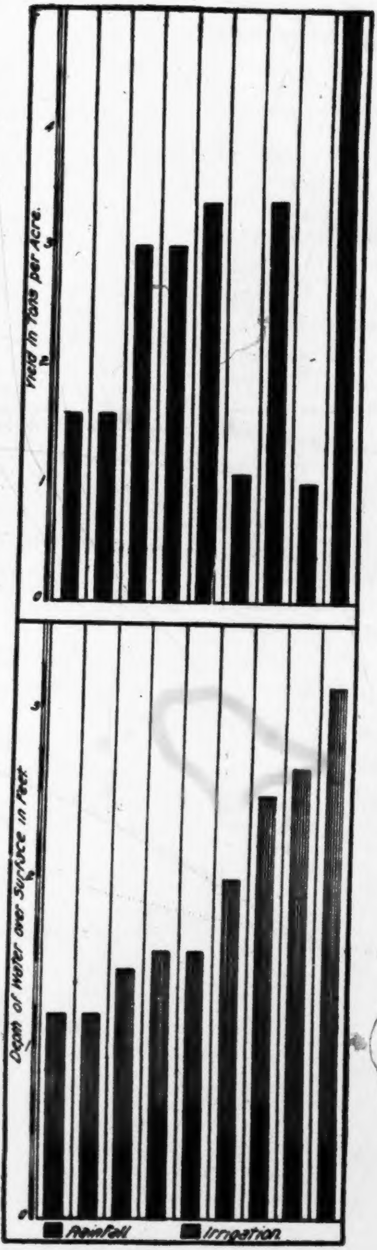

FIG. 9.—Depth of water received by clover, and yields.

measure either a large canal or a stream by means of a miner's-inch box, all measurements were made in cubic feet per second, according to modern methods, and afterwards reduced to miner's inches.

Prior to 1885 Montana had no legal standard for measuring water in motion. In that year the legislature enacted the following somewhat imperfect description of a measuring box:

> SEC. 1262. The measurement of water appropriated under this chapter shall be conducted in the following manner: A box or flume shall be constructed with a head gate placed so as to leave an opening of 6 inches between the bottom of the box or flume and the lower edge of the head gate, with a slide to enter at one side of and of sufficient width to close the opening left by the head gate by means of which the dimensions of the opening are to be adjusted. The box or flume shall be placed level and so arranged that the stream in passing through the aperture is not obstructed by back water or an eddy below the gate, but before entering the opening to be measured the stream shall be brought to an eddy and shall stand 3 inches on the head gate and above the opening. The number of square inches contained in the opening shall be the measure of inches of water.

For thirteen years the miner's-inch box just described was the only legal means of measuring irrigation water, and all court decrees which were rendered from 1885 to the spring of 1898 and which deal with specified volumes of water used in irrigation are expressed in Montana statutory inches. While a new standard unit has been adopted, the old unit can not be said to be wholly abolished. Parties whose rights to the use of water were established during this thirteen-year period have been granted the privilege of having the quantity of water to which each is entitled measured by the miner's-inch box.[a]

Since 1898 the standard unit in Montana for the measurement of water in motion is the cubic foot per second, a cubic foot of water moving at the rate of 1 linear foot in one second of time. In adopting a new standard the members of the Montana legislature foresaw the extended use of the old unit and so defined it in accurate terms. Forty miner's inches are the exact equivalent of 1 cubic foot per second and the volume of 1 miner's inch is equal to 0.025 cubic foot per second.

The miner's inch and the cubic foot per second can only be used to measure water in motion. Since it is often convenient to describe a certain quantity of water in a state of rest, the acre-foot has been quite generally adopted for this purpose. It means the amount of water that will cover 1 acre to a depth of 1 foot, or 43,560 cubic feet, or 325,851 United States gallons.

HOW MEASUREMENTS WERE MADE.

In ascertaining the amount of water applied to individual crops it was customary to measure the stream at the upper boundary of the field. This was done in most cases by placing a Cipolletti weir of the proper size in the supply ditch. The canals were measured at rating flumes placed near the point of diversion, the velocity being determined by a current meter. In the Gallatin Valley the fluctuations in the water levels of both the small ditches and the canals were measured and recorded by a recording instrument, but in the Bitter Root and Yellowstone valleys no instruments were available, and daily observations were made of the height of water at the several gauges by the ditch riders, who kept the records in a book provided for that purpose.

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[a] See description by author in Montana Sta. Bul. 34, p. 4.

In fenced fields the area contained within the fence lines was taken, but in smaller fields only the area cropped, together with the space occupied by the head ditches, was included. The area of land under most of the canals investigated in the Bitter Root Valley was found by actual survey. From 1889 to 1901, inclusive, on account of the lack of funds, no surveys were made of the Yellowstone or Gallatin Valley canals. The total area irrigated under each canal was computed from estimates obtained from the owners by a house-to-house canvass. In 1902 careful surveys were made of the irrigated lands under each canal, thereby checking the estimates of previous years.

THE QUANTITY OF WATER APPLIED TO INDIVIDUAL CROPS.

MEASUREMENTS MADE IN 1899.

In 1899 an effort to determine the duty of water in the Gallatin Valley was made by the irrigation and drainage investigations of the Office of Experiment Stations, United States Department of Agriculture, in cooperation with the Montana Experiment Station. In selecting the fields care was taken to have them represent as nearly as possible the average conditions of that vicinity. No attempt was ever made to control the amount of water used. The farmer was free to use as much water as he deemed necessary. The work for the first season consisted in determining the amount of water applied to eight fields and the duty of water under Middle Creek canal. Five of the field tests were made on the station farm and the remaining three on adjacent farms. Descriptions of these fields were published in a former bulletin.[a] The soil in general consists of a clay loam from 30 to 70 inches deep, with a porous stratum of gravel wash beneath. No water was used on any of the eight fields before June 17, 1899, and on that date the irrigation of a field of red clover was begun. It was June 23 when the first of the seven grain fields was irrigated, and no water was applied on these after July 26. The last watering of the clover field took place August 2. In the following table are given for each field the number of acres irrigated, the yield per acre, the rainfall during the period of growth, and the duty.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 86.

Summary of results of duty of water experiments on field crops in Gallatin County, in 1899.

Crop.	Area irrigated.	Yield per acre.	Number of irrigations.	Rainfall during growth.	Depth applied.
	Acres.			*Foot.*	*Feet.*
Clover	27.44	3 tons	3	0.44	1.02
Peas	4.23	31.25 bushels	2	.41	1.10
Grain	11.27	57.89 bushels	2	.42	1.98
Barley	66.39	73 bushels	1	.41	.98
Oats	23.41	51 bushels	1	.38	1.53
Do	7.26	72.75 bushels	2	.36	1.34
Do	2.48	72.75 bushels	2	.36	2.16
Do	25.09		1	.44	1.28

MEASUREMENTS MADE IN 1900.

The measurements made in 1900 to determine the duty of water on individual fields were not confined to the Gallatin Valley, but were extended to the Bitter Root and Yellowstone valleys.[a] The crops tested in the Gallatin Valley were grain and red clover. Water was first used June 4 and its use was continued until August 14. The clover crops were irrigated from two to four times and the grain crops were each irrigated twice. The former received on an average 18 inches in depth, of which 4 inches was rain; the latter received 26.5 inches, of which nearly 5 inches was rain.

The quantity of water applied to three fields belonging to the Bitter Root stock farm of Ravalli County was determined. The first of these consisted of a 40-acre tract of 5-year-old orchard trees. A light vegetable loam formed the top soil, with a subsoil of gravel and small cobbles. Light irrigations were applied in April, June, July, and August, but the aggregate of the four with the rainfall was only 18 inches in depth over the surface. The quantity of water applied in two irrigations to a large field of oats on the same stock farm was 17 inches.

The third experiment was made on a high gravelly bench traversed by numerous ravines, and much of the water used was apparently wasted. The yield of oats averaged 34 bushels, and yet the volume applied in two irrigations would have covered the tract of 102.2 acres to a depth of 6 feet.

In Yellowstone County the amount of water used on a field of alfalfa comprising 53.4 acres was measured. Three crops were grown with only one heavy irrigation. The yield per acre for the season was 5.17 tons, and the depth of water applied was 16 inches. This practice of raising so many crops with one application of water is not representative of this alfalfa-raising district. Many raise four crops in one season, and water the land for each crop. In doing so each irrigation would be comparatively light, probably not over 9 inches, or 36 inches for the season. The results at all these places in 1900 are given below.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 104, pp. 267-292.

Summary of results of the duty of water experiments on field crops made in 1900.

Crop.	Area irrigated.	Yield per acre.	Number of irrigations.	Rainfall.	Depth applied.
	Acres.			*Foot.*	*Feet.*
Clover[a]	66.39		2	0.44	1.98
Barley[a]	4.14	48.50 bushels	2	.28	1.50
Oats[a]	25.09		2	.39	.84
Wheat[a] Clover[a]	2.00	38.33 bushels 3,170 pounds	2 2	.30	.77
Oats[a] Peas[a]	2.00	75.58 bushels 1,330 pounds	2 2	.39	.57
Barley[a]	1.00	87.29 bushels	2	.28	1.17
Oats[a]	8.51	74.67 bushels	2	.40	1.27
Barley[a]	4.52	68.58 bushels	2	.42	1.96
Clover[a]	7.26	5 tons	4	.44	2.70
Do.	35.90		3	.44	1.78
Alfalfa[b]	58.41	5.17 tons	1	.45	1.30
Orchard[c]	40.00		4	.13	1.48
Oats[c]	161.70	33 bushels	2	.13	1.28
Do.	102.20	34 bushels	2	.13	6.00

[a] Gallatin County. [b] Yellowstone County. [c] Ravalli County.

MEASUREMENTS MADE IN 1901.

The investigations of 1901 were a continuation of those conducted in former years.[a] The crops of Gallatin County were six clover fields, seven grain fields, and one sugar-beet field. The clover crops were irrigated from one to three times and the average quantity of water applied during the season was 14.5 inches. To this should be added the rainfall, which averaged 7.2 inches, making a total of 21.7 inches. The amounts applied to seven grain crops were a trifle less than 12 inches of irrigation water and nearly 6 inches of rain water, or 18 inches in all. The sugar beets were irrigated three times and received 24.6 inches in both irrigation and rain water.

The same three fields in Ravalli County on which water was measured in 1900 were tested in 1901. The 40-acre tract of 6-year-old orchard trees was again watered four times and the average depth of water used in irrigation was 18.7 inches, while the rainfall was 5.9 inches, a total of 24.6 inches. The second field produced 150 tons of clover hay with the use of 18 inches of irrigation water and 6 inches of rainfall; and the third field, on which so much water had been applied the year previous, produced 103 tons of clover hay with the use of 5.5 inches of rainfall and 26.5 inches of ditch water.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 119, pp. 225-241.

Summary of results of duty of water experiments on field crops made in 1901.

Crop.	Area irrigated.	Yield per acre.	Number of irrigations.	Rainfall.	Depth applied.
	Acres.			*Foot.*	*Feet.*
Clover[a]	20.86	3.36 tons	2	0.65	0.92
Do	5.59		3	.67	1.81
Do	7.13		2	.62	1.24
Do	6.85		3	.62	1.55
Wheat[a]	5.25	43.20 bushels	2	.45	1.20
Do	3.00	42.90 bushels	2	.43	.77
Barley[a]		61.50 bushels			
Clover[a]		1.59 tons			
Sugar beets[a]	1.00	10 tons	3	.59	1.46
Oats[a]	15.35	73 bushels	2	.43	1.63
Clover[a]	27.84	3 tons	1	.62	.95
Barley[a]	12.47	59 bushels	1	.46	.85
Peas[a]	8.41	37.50 bushels	1	.77	.35
Oats[a]	37.30		1	.45	1.27
Orchard[b]	40.00		4	.49	1.56
Clover[b]	161.70	0.90 ton	3	.49	1.50
Do	102.00	1 ton	4	.45	2.22
Alfalfa[c]	53.41			.59	1.14

[a] Gallatin County.
[b] Ravalli County.
[c] Yellowstone County.

MEASUREMENTS MADE IN 1902.

In beginning the field tests in the spring of 1902, advantage was taken of the weir boxes already in place, which had been used in previous years. On account of the long season, the spring being early and a plentiful supply of water in the streams, more water was used. In Gallatin County three crops of clover and one crop of alfalfa received on an average for all four crops 20.8 inches of ditch water and 9.4 inches of rain water, while five grain crops received 18 inches from irrigation and 7.4 inches from rainfall.

In Ravalli County a record was kept of the amount of water applied to each of the fields previously described, and the average is considerably higher, being for the three fields 28.1 inches of irrigation water and 7.9 inches of rain water.

Summary of results of duty of water experiments on field crops made in 1902.[a]

Crop.	Area irrigated.	Number of irrigations.	Rainfall.	Depth applied.
	Acres.		*Foot.*	*Feet.*
Barley[b]	19.80	2	0.64	0.97
Rotation plats[b]	6.00	2	.64	1.04
Wheat[b]	5.62	2	.72	2.44
Oats[b]	3.38	2	.54	1.28
Clover[b]	9.72	2	.78	1.65
Oats[b]	8.93	2	.54	1.77
Alfalfa[b]	4.02	2	.78	1.00
Clover[b]	27.84	1	.78	1.00
Do[b]	81.30		.78	3.13
Orchard[c]	40.00		.66	1.77
Clover[c]	161.00		.66	1.30
Do[c]	102.00		.66	3.95

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 133, pp. 137-150.
[b] Gallatin County.
[c] Ravalli County.

MEASUREMENTS MADE IN 1903.

During the season the flow of a large number of canals was measured for the purpose of ascertaining the duty of water under each, but few results were obtained from fields. The depth of water applied to a clover field in the Gallatin Valley, owned by Mr. J. L. Patterson, was 11.2 inches. Another clover field in the same valley, owned by Mr. John M. Robinson, received a depth of 20.2 inches. A third field of timothy and clover, owned by State Senator C. W. Hoffman, received in one irrigation a depth of 7.9 inches.

In the Bitter Root Valley a clover field received a depth of 16.4 inches. The yield was 1.94 tons per acre. A second clover field located on the Bitter Root stock farm received 94.1 inches, yet the yield was only 2.04 tons per acre, or a trifle more than that of the field where only about one-sixth the amount of water had been used.

Summary of results of duty of water experiments on field crops made in 1903.

Crop.	Area irrigated.	Yield per acre.	Number of irrigations.	Rainfall.	Depth applied.
	Acres.	*Tons.*		*Feet.*	*Feet.*
Clover	27.84	....	1	1.03	0.94
Do	81.30	....	1	1.03	1.69
Timothy and clover	37.33	....	1	1.03	.66
Clover	161.70	1.94	2	.40	1.37
Do	102.00	2.04	4	.40	7.84

QUANTITY OF WATER APPLIED TO LAND UNDER TYPICAL CANALS.

The quantity of water diverted by canals is in all but the most exceptional cases much larger than that delivered by it to fields. This difference is due to losses by percolation and evaporation. In addition to the losses water is frequently allowed to flow from the canals over waste ways. This water may return to the natural channel of the stream, or it may be wasted. In the spring of the year when water is plentiful many Montana canals carry an excess which is permitted to flow through waste gates unutilized. The same is true of the period near the close of the irrigation season or during a rainy spell. At such times more water is turned in at the head than the farmers care to use. In determining the duty of water under a canal it is customary to measure the flow daily at some suitable place near the head gate and to consider the volume which passes this point in the season in determining the duty of water for that particular canal. Losses due to the causes just named may be determined and an allowance made for them; but these will be considered under the term "seepage" in another part of this report. In the statement of duty of water under canals contained herein no deduction has been made for any of the losses just named.

THE BIG DITCH OF YELLOWSTONE COUNTY.

Yellowstone County, lying between the Musselshell River on the north and the Yellowstone River on the south, contains about 2,370,000 acres, a large part of which is arable. The Yellowstone River is the chief source of water, but owing to the difference in elevation between the large part of the arable land and the stream, which has a somewhat low grade for at least 100 miles above, only a portion of the arable land can be reached. At the present time the reclaimed land is found in the valleys bordering the river and separated from the higher bench lands by high walls of stratified sand rock.

The Big ditch is the largest one in the county and one of the largest in the State. Its capacity in 1903, as compared with the principal canals in this county, may be seen from the results of discharge measurements made in 1903, and given below:

Discharge of Yellowstone County ditches.

	Cubic feet per second.
Big ditch	383
Canyon Creek ditch	60
Italian ditch	56
Yellowstone ditch	36
Merril ditch	31
Mill ditch	29
Flaherty Flat ditch	22

It was completed over twenty years ago at a cost of $110,000, but the area irrigated was quite small for the first few years. It was maintained and operated by an investment company until May, 1900, when it was purchased by the farmers who owned land under it, and became a cooperative canal. It is managed by a board of trustees annually elected by the stockholders from among their number. The price paid was $64,000, which was divided into shares of the par value of $10 each. In 1902 there were 132 stockholders whose shares varied in number from 1 to 385 and averaged 47 shares each. In July, 1904, the number of stockholders had increased to 158, and the maximum number of shares held by one man decreased to 377.

Prior to 1900 little was known of the capacities of any of the Yellowstone County ditches, or of the duty of water under them. The flow was supposed to be divided among the water-right owners in miner's inches, but the prevalent idea regarding a miner's inch was one of about double the discharge of the statutory inch. In the spring of that year three measuring stations were established on the Big ditch and a daily record kept of the flow at each from May 25 to September 27. The first of these stations was at Tilden's ranch, about 5 miles below the head gates on Yellowstone River, the second at Park City, and the third at the Hesper farm, located 11 and 27 miles, respectively, below the head gates. There were no diversions above Tilden's ranch. The canal terminated on the bench above the town of Billings, the total length being 39 miles.

The extent of land irrigated under the Big ditch was ascertained in 1901 and 1902 by a house-to-house canvass, but during the summer of 1903 a survey was made of each farm irrigated from the canal. Inasmuch as the irrigated area, as determined by the survey in 1903, was somewhat less than that of previous years, the latter may have been overestimated. On the other hand, there is a possibility that less land was irrigated in 1903. As will be seen from the following table, alfalfa is the prevailing crop, and meadow land, which comprises timothy and blue joint, as well as irrigated pasture, ranks second.

Acreage of crops irrigated under Big ditch for the years named.

	1901.	1902.	1903.		1901.	1902.	1903.
	Acres.	*Acres.*	*Acres.*		*Acres.*	*Acres.*	*Acres.*
Alfalfa	8,270	8,894	8,383	Garden	550	610	615
Meadow	6,309	6,243	3,664	Corn	352	358	169
Oats	1,885	3,117	3,401				
Wheat	778	816	918	Total	18,144	20,038	17,145

The daily measurements of discharge begun in 1900 have been continued for four years, and the results of measurements made at Tilden's ranch are summarized in the following table, together with the depths to which this would cover the land irrigated:

Discharge of Big ditch at Tilden's ranch for 1900 to 1903, inclusive.

Month.	1900, discharge.	1901.		1902.		1903.	
		Discharge.	Depth.	Discharge.	Depth.	Discharge.	Depth.
	Acre-feet.	*Acre-feet.*	*Feet.*	*Acre-feet.*	*Feet.*	*Acre-feet.*	*Feet.*
May	2,193	6,212	0.34	10,198	0.51	682	0.04
June	14,643	9,980	.55	15,560	.78	10,647	.62
July	13,317	16,243	.90	19,135	.95	21,475	1.25
August	9,991	14,070	.78	17,489	.87	9,577	.56
September	6,852	....	....	11,443	.57	16,454	.96
October	....	....	....	....	....	11,772	.69
Total	46,996	46,505	2.56	73,825	3.68	70,607	4.12

It will be seen from the foregoing statement that the volumes used in 1900 and 1901 are about equal, but that a large increase occurred in 1902 and 1903. This is due to improvements and enlargements. In order to expedite this work no water was run in the canal during the month of September, 1901. There is an apparent decrease in the volume carried in 1903 over that of the preceding year, but this is due to two shut downs, the first of which lasted from May 14 to May 31, and the second from July 27 to August 17. As a matter of fact, the maximum volume carried in 1903 exceeded that of 1902 by nearly 25 per cent.

The diagram (fig. 10) illustrates the daily flow of the Big ditch in 1903, and the average quantity of water which was applied to the land each month of the irrigating season. The ditch was closed for repairs from June 14 to July 1 and from July 26 to August 17, which greatly reduced the amounts of water applied to land in June and August.

Considering that alfalfa and meadow lands, both of which require large amounts of water, were the principal crops, and that a large percentage of the water taken from the river was either lost in transit or permitted to flow through waste ways unutilized, the conclusion is justified that one-half of a miner's inch per acre is a fair average for the duty of water in Yellowstone County. Yellowstone County in climate, products, and physical characteristics is similar to much of the land bordering on the Yellowstone River. One may, therefore, go further and state that as an average one-half a miner's inch of water per acre will suffice for the counties of Park, Yellowstone, Sweet Grass, Carbon, Rosebud, Custer, Dawson, and the Crow Reservation, or a total of 2,925,000.

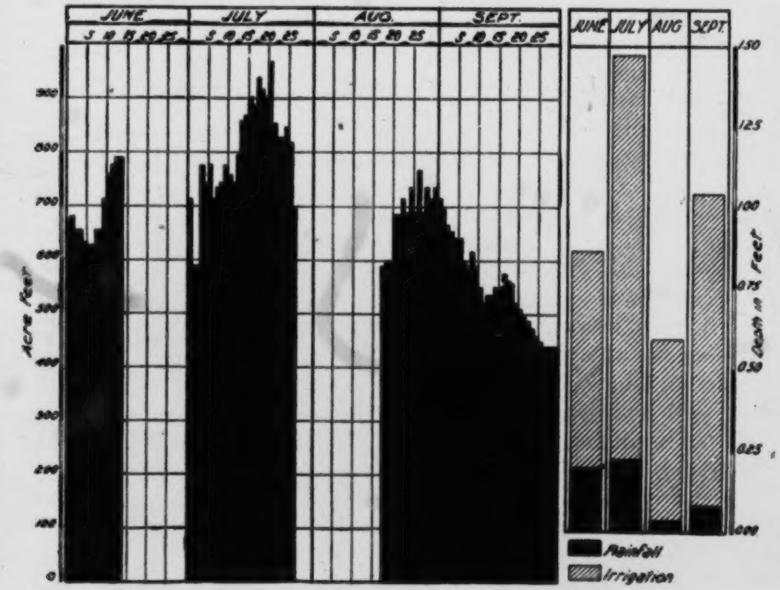

FIG. 10.—Daily discharge of Big ditch, and depths of water received by lands thereunder, 1903.

CANALS OF GALLATIN COUNTY.

MIDDLE CREEK CANAL.

Middle Creek canal is the largest of some thirteen ditches which divert water from Middle Creek, a tributary of the Gallatin River. The summer flow of this creek (see p. 20) is wholly diverted and utilized to irrigate farms located in the upper or southeastern part of Gallatin Valley. The top layer of soil in this section consists of rich vegetable loam. In the most fertile portions this vegetable loam gradually changes into clay loam and clay marl but in other portions the coarse gravel and cobbles which underlie all are found within a foot of the surface. Considerable rain and soft snow fall in April, May, and June of each year, and in moderately wet springs this is sufficient for the needs of the crops until about July 1. In other years, when the spring crops are seeded early, or when the weather is warm and dry, water is applied in June and occasionally in May to meadows.

The grade of Middle Creek, particularly at the upper end, is excessive. In a total length of 18,000 feet the fall is 170 feet, or on an average of nearly 50 feet per mile. Owing to the high velocity, the channel is washed clean of all earth and fine sand, and only coarse gravel and cobbles remain. The loss by seepage is thus large in proportion to the volume carried (see p. 90). Notwithstanding this heavy loss, the duty of water as measured during the past five years has been reasonably high. The rating flume at which water measurements have been made is located about 200 feet below the intake, so that all losses in transmission are included. This record is valuable in that it extended through a period of five consecutive years, which included seasons of scanty as well as seasons of abundant rainfall. Compared with average amounts used in other parts of Gallatin Valley and other parts of the State, this duty is high, being at the rate of 1 miner's inch for nearly 8 acres of land. At the same time the yield and value of the crops under Middle Creek canal have not appeared to suffer in the least on account of the small quantity of water used, since for the period under consideration they have been fully equal to those of other sections of Gallatin Valley and superior to those of many other parts of the State.

Barley and hay are the principal crops under this canal. Some ten or fifteen years ago little but grain was raised, and in order to increase the diminishing yields recourse was had to summer fallowing. A field which produced barley, wheat, or oats for one or two years was summer fallowed for one season and then replanted to grain. Largely through the efforts of the Montana Experiment Station this wasteful method of irrigated farming was changed to one of scientific rotation. It was demonstrated repeatedly that better crops were obtained after red clover than after summer fallowing, and in consequence much of the land which remained idle every alternate year is now producing red clover or alfalfa. It was likewise shown by the same agency that the climate and soil of Gallatin Valley were peculiarly adapted to the growth of brewing barley, which accounts for the large acreage in this crop.

Acreage of irrigated crops under Middle Creek canal for 1899.

	Acres.
Barley	1,438
Oats	597
Wheat	118
Timothy and clover	1,405
Clover and alfalfa	147
Other crops	148
Total	3,853

The areas watered were: 1899, 3,853 acres; 1900, 3,853 acres; 1901, 3,168 acres; 1902, 4,828 acres; 1903, 4,828 acres.

Duty of water under Middle Creek canal for the years 1899, 1900, 1901, 1902, and 1903.[a]

Month.	1899.		1900.		1901.		1902.		1903.	
	Discharge.	Depth.	Discharge.	Depth.	Discharge.	Depth.	Discharge.	Depth.	Discharge.	Depth.
	Acre-ft.	*Feet.*	*Acre-ft.*	*Feet.*	*Acre-ft.*	*Feet.*	*Acre-ft.*	*Feet.*	*Acre-ft.*	*Feet.*
May	....	....	....	....	....	....	263	0.05	....	....
June	1,539	0.40	3,917	1.01	2,222	0.70	3,091	.64	2,898	0.60
July	4,610	1.20	1,912	.50	2,973	.93	1,363	.28	1,515	.31
August	903	.23	1,075	.28	1,541	.48	857	.18	1,523	.32
September	1,022	.27	420	.11	718	.22	....	....	1,201	.25
Total	8,074	2.10	7,324	1.90	7,454	2.33	5,577	1.15	7,137	1.48

[a] See diagram, fig. 11.

OTHER CANALS FROM MIDDLE CREEK.

Besides the Middle Creek canal there are 12 smaller ditches, which tap the same source. These 13 ditches divert the entire flow of Middle Creek after the spring flood has subsided. The maximum flow occurs from March 10 to June 20 of each year. When the highest water occurs in the second week of June the daily decrease in the stream is so great that all the flow is utilized before July 1, but when it occurs as late as the third week in June there may be an excess of water which is discharged into the East Gallatin and from thence into the Missouri River during the first week in July. As a rule, however, there is no surplus after July 1.

The following figures on the summer flow of Middle Creek have been computed chiefly from measurements made by the United States Geological Survey at the mouth of Middle Creek Canyon and about 1 mile above the highest ditch which diverts water for irrigation.

Monthly discharge in acre-feet of Middle Creek for the years named.

Month.	1898,	1899.	1900.	1902.
May	16,610	8,150	....	6,150
June	25,521	29,982	5,750	13,250
July	10,586	20,559	5,500	7,115
August	3,989	6,383	3,460	3,662
September	3,178	3,414	2,870	2,970
October	2,255	2,987	1,240	304
Total	62,139	71,475	18,820	33,451

During the summer of 1902 the acreage of crops irrigated under Middle Creek was ascertained by a plane-table survey. For convenience and to lessen the expense the crops were grouped. Thus all the cereals, such as barley, wheat, and oats, were included under the general term of grain crops; alfalfa, clover, timothy, and forage crops generally were grouped under hay crops; irrigated pasture lands formed a third group; vegetables, root crops, and orchards were included under garden crops, and all summer-fallowed land was kept separate from cropped areas.

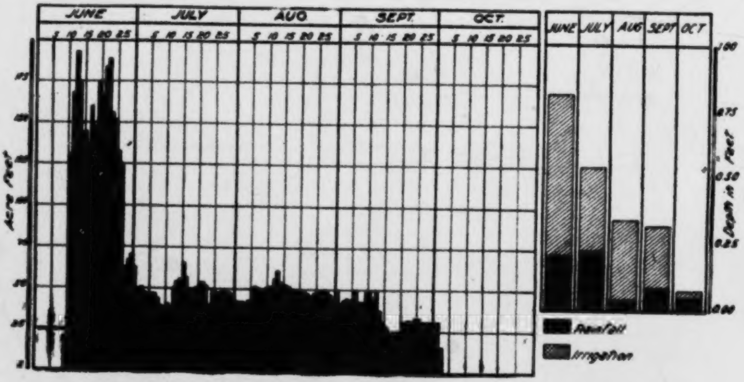

Fig. 11.—Daily discharge of Middle Creek canal, and depth of water received by land, 1903.

Acreage of crops irrigated by 13 ditches diverting water from Middle Creek in 1902.

	Acres.
Grain	2,944
Hay	5,284
Pasture	678
Garden	62
Total	8,986
Area in summer fallow	1,366
Total cultivated area	10,334

In computing the duty of water under Middle Creek for the season of 1902 the amounts used in July, August, and September were accurately determined, since the entire flow of the stream was diverted during these three months. In June, however, there was a surplus which was not measured, and for that month the duty is estimated as follows: The total discharge for June was 13,250 acre-feet and for July 7,115 acre-feet. As a rule, more water is used on the Middle Creek farms in July than in June, but in arriving at the estimate the utilized flow during June was made equal to that during July. The duty of water for the season, as expressed in the following table, thus becomes 2.33 feet in depth over the surface of 8,968 acres, which corresponds to the continuous flow of 1 cubic foot per second for 104 acres, or of 1 miner's inch for 2.1 acres.

Duty of water under Middle Creek for the year 1902, June to September, inclusive.

Area irrigated	acres	8,968
Water used	acre-feet	20,862
Depth	feet	2.33
Acres per cubic foot per second		104
Acres per miner's inch		2.60

WEST GALLATIN IRRIGATION COMPANY'S CANAL.

This canal, which is one of the largest in Gallatin County, gets its supply from the West Gallatin River. The intake is located at the mouth of the canyon, and from this point the canal winds around the river bluffs in a northwesterly direction for about 40 miles. The formation varies from a loose vegetable loam on top to sand, gravel, and bowlders beneath, overlying a soft sand rock. The softer portions of this sand rock are readily disintegrated by seepage water from the canal, and whenever the top of this stratum coincides with the bottom of the excavated canal, it is difficult to prevent water from percolating between the subsoil and this rock stratum. These unfavorable conditions have caused a number of bad breaks in the upper portion of the canal. The losses due to seepage on the main canal, described elsewhere (see p. 88), form about one-third of the total volume admitted at the intake. Small additional losses occur along the lines of the various laterals. Then, too, much of the land under this canal is undulating, with steep slopes cut up by ravines, and in attempting to spread water over the surface more or less runs off and serves no useful purpose. These physical conditions, coupled with a somewhat porous soil and crude methods of irrigation, account for the large quantity of water which was applied to land under this canal in 1902. The area irrigated was 2,343 acres.

Duty of water under West Gallatin Irrigation Company's canal for 1902.

Month.	Discharge.	Depth.
	Acre-feet.	*Feet.*
May	569	0.24
June	3,613	1.54
July	5,555	2.37
August	2,729	1.17
Total	12,466	5.32

KUGHEN OR CAMERON CANAL.

This canal is one out of fifty-four which divert water from the West Gallatin River. It is owned and controlled by a small community of farmers, whose farms are located in the upper portion of the central belt of Gallatin Valley. Of the canals which take water from the left or west bank of the river it ranks next in capacity to the West Gallatin Irrigation Company's canal. It is nearly 11 miles long, has a bottom width of 11 to 12 feet, and a depth of 2 to 3 feet near the head and is capable of carrying some 80 cubic feet of water per second. The losses due to seepage are small. At the same time, the duty of water is low. This is largely due to the fact that this ditch possesses one of the oldest rights on the river, and has recently been enlarged to carry an abundant supply for the comparatively small area of land which it irrigates, much more in fact than the crops require.

The crops irrigated in 1902 are shown in the following table:

Acreage of irrigated crops under the Kughen canal for 1902.

	Acres.
Barley	899
Oats	423
Flax	122
Timothy	80
Pasture	25
Wheat	12
Clover	3
Total	1,564

During the same year 1,379 acres, or nearly one-half the total cultivated area was summer fallowed. If the excess water which was wasted in irrigating 1,564 acres had been applied to the 1,379 acres of fallow land, the additional yield in 1902 from the thirteen farms under this canal would have, in all probability, had a gross value of $27,000.

The discharge of the ditch and the depth to which it would cover the land are shown in the following table:

Duty of water under the Kughen canal in 1902 and 1903.

Month.	1902.		1903.	
	Discharge.	Depth.	Discharge.	Depth.[a]
	Acre-feet.	*Feet.*	*Acre-feet.*	*Feet.*
June	2,643	1.69	1,985	1.27
July	3,604	2.30	3,862	2.47
August	1,079	.69	1,712	1.09
September	....	....	1,488	.95
Total	7,326	4.68	9,047	5.78

[a] The area irrigated in 1903 is assumed to be the same as in 1902.

Figure 12 shows the flow of this canal in 1903 and likewise the amounts of water applied to the land during each month.

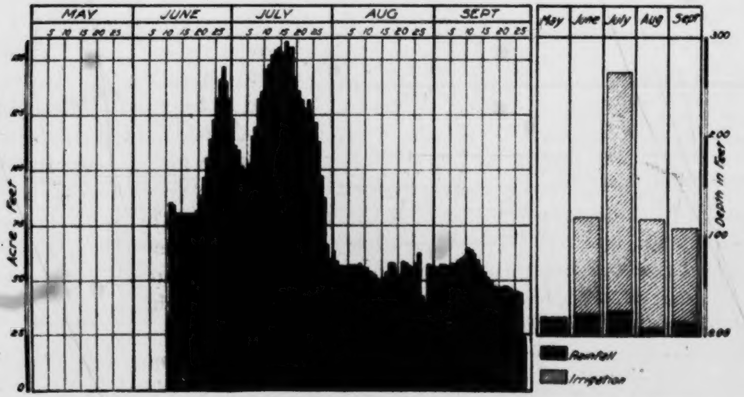

FIG. 12.—Daily discharge of Kughen canal, and depth of water received by land, 1903.

CANALS OF RAVALLI COUNTY.

The land of Ravalli County, which contains in round numbers 1,850,000 acres, may be divided into three classes. The western and to a considerable extent the southern part of the county is well timbered and mountainous. Through the central portion flows the Bitter Root River, on either side of which are to be found large tracts of arable and irrigable land, and in the east the land is undulating and hilly and chiefly devoted to grazing. On the west of the Bitter Root River, which flows north to meet the Missoula, the dense groves of pines, firs, and tamaracks extend from the borders of the valley and in many places from the river bank to the summit of the Bitter Root Range, from 10 to 15 miles distant. On this steep mountain slope, which rises at times 5,000 feet in 5 miles, the green of the pines makes a vivid contrast with the snow-capped peaks of the range, which rise to heights of 9,000 to 10,000 feet. At the foot of this forest slope is a typical mountain stream, the water of which, except in flood time, is unusually clear. Throughout the long valley diversified farming is practiced. All kinds of cereals do well. Red clover and timothy seem to be preferred in places to alfalfa. The soil is peculiarly well adapted to vegetables, and both soil and climate are admirably suited to fruit raising. The apple, plum, cherry, and in fact all the hardier varieties of deciduous fruit trees appear to have found in the Bitter Root Valley ideal conditions for their growth. Sheltered from the west winds by the Bitter Root Mountains and from the east winds by the main range of the Rockies, the valley possesses a much more moderate climate than many fruit-producing regions which lie far to the south of Montana. The altitude is low compared with much of the irrigated portion of the West, being about 3,200 feet above sea level at the lower end and rising to 3,800 feet at the upper end. The granite soil is light and porous, with a large percentage of sand and gravel. In the lower valleys the soil is frequently a rich vegetable loam, and to the east of the river there are large tracts of heavier soils containing more or less clay. The land to the west of the river is abundantly supplied with water. Numerous creeks, which are fed by the heavy snowfall of the Bitter Root Range and forest reserve, are easily diverted by short ditches. As may be expected, the duty of water throughout this part of the valley is low. The soil is porous and underlaid by a mass of rock débris from the mountains, so that any excess of water which may be applied soon returns to the main channel of the stream without producing, it is thought, any injurious effects upon the soil.

East of the river conditions are different. The mountains to the east being low, the precipitation, particularly in the form of snow, is light, and in consequence there are few creeks in this part of the basin. Yet on this side the larger tracts of fertile lands are located, and for their irrigation water has been conveyed from the Bitter Root River in canals of considerable size. The most of these canals were begun by small communities of farmers in the eighties, and the majority are still maintained and operated by the landowners and water users under them. Other canals that were begun during the early development of this part of the State have passed into the hands of capitalists.

In 1900 advantage was taken of this large tract of irrigated land and its excellent system of irrigation canals to gain more knowledge concerning the use of water in irrigation and the seepage losses from canals. The investigations then begun have continued since, and during the entire period the Office of Experiment Stations and the Montana Experiment Station have been greatly assisted by the officers of the Bitter Root stock farm. The irrigation system was intended to cover more land than has since been irrigated, and the water supply is ample, so that the economical use of water has never been a necessity. Another cause for low duty is the large area of new land which has been recently brought under irrigation, requiring an additional amount of water. And, finally, much of the land is porous, gravelly soil on elevated benches, with more or less ravines and steep slopes. The results obtained under such conditions should represent the maximum use in Montana.

REPUBLICAN CANAL.

This canal was begun by farmers in the vicinity of what is now the city of Hamilton, the county seat of Ravalli County. In 1889 the stockholders changed the point of diversion and the source of supply on Skalkaho Creek to the Bitter Root River near the junction of the tributary known as Sleeping Child.

The area of land irrigated was determined by actual survey. The areas irrigated were, in 1901, 4,105 acres; in 1902, 4,850 acres; and in 1903, 4,850 acres. The manner in which this area was utilized in 1903 to raise the standard crops is shown in the following table:

Acreage of crops irrigated under Republican canal in 1903. [a]

	Acres.
Wheat	201
Oats	210
Pasture	681
Meadow	758
Peas	6
Roots and vegetables	20
Orchards	61
Total	1,937

In the following table are given the volumes discharged by the canal in acre-feet for each month of the irrigation season for the years 1901, 1902, and 1903, with the depths to which this would cover the total irrigated area:

Duty of water under Republican canal for the years 1901, 1902, and 1903.

Month.	1901.		1902.		1903.	
	Discharge.	Depth.	Discharge.	Depth.	Discharge.	Depth.
	Acre-feet.	*Feet.*	*Acre-feet.*	*Feet.*	*Acre-feet.*	*Feet.*
April	1,608	0.39				
May	3,115	.76	3,442	0.71	3,043	0.63
June	2,116	.52	4,372	.90	3,852	.80
July	3,656	.89	3,995	.82	2,810	.58
August	3,263	.79	5,826	1.20	2,602	.54
September			4,251	.88	1,940	.40
Total	13,758	3.35	21,886	4.51	14,247	2.95

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[a] Exclusive of Patterson laterals and outside water users.

Figure 13 shows the daily flow of the Republican canal in acre-feet during the season of 1903, and also the depth of water received by the land each month.

SKALKAHO CANAL.

This canal was built for the purpose of irrigating about 2,000 acres of land located above the Ward canal. It is 7 miles long, and over one-third of this distance the water is carried in either a wooden flume or redwood-stave siphon. The siphon is 36 inches in diameter and the flume has a sectional area of 12.5 square feet. On a grade of 0.1 foot to the hundred feet the mean velocity is about 5 feet per second, thus producing a maximum discharge of over 60 cubic feet per second. Sixteen hundred acres were irrigated in 1901, and 1,975 acres in 1902 and 1903. The monthly discharge and depths to which this would cover the land is given below:

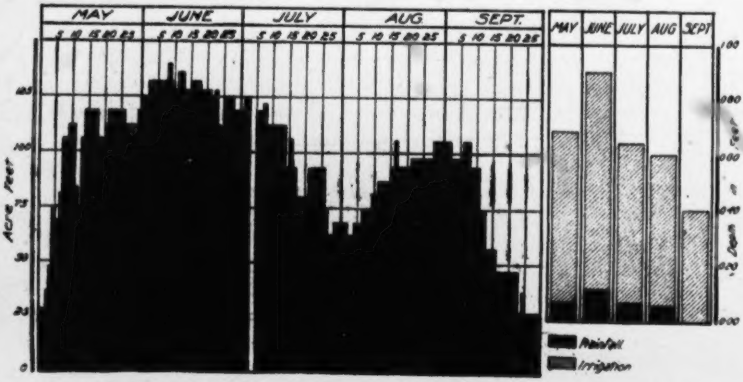

Fig. 13.—Daily discharge of Republican canal, 1903, and depth of water received by land.

Duty of water under Skalkaho canal for 1901, 1902, and 1903.

Month.	1901.		1902.		1903.	
	Discharge.	Depth.	Discharge.	Depth.	Discharge.	Depth.
	Acre-feet.	*Feet.*	*Acre-feet.*	*Feet.*	*Acre-feet.*	*Feet.*
April	506	0.32	469	0.24	490	0.25
May	1,775	1.11	2,097	1.06	1,936	.98
June	1,477	.92	3,336	1.69	3,040	1.54
July	2,290	1.43	3,335	1.69	3,308	1.67
August	1,447	.90	2,582	1.31	2,314	1.12
September			1,618	.82	1,542	.98
Total	7,495	4.68	13,437	6.61	12,630	6.34

GIRD CREEK DITCHES.

The waters of Gird Creek, which flow from the mountains on the east side of the Bitter Root Valley, are diverted on the lands of the Bitter Root stock farm by three canals. One diverts water to the south and the water is mixed with that from the Skalkaho canal; the other two carry water to the bench north of Gird Creek, and are known respectively as the Old Gird canal north and the New Gird Creek canal north. The monthly discharge of the Gird Creek canals is as follows:

Monthly discharge of Gird Creek canals for 1901, 1902, and 1903.

Month.	1901.	1902.	1903.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*
April	....	291	240
May	....	1,998	2,163
June	....	3,658	4,592
July	....	2,833	3,756
August	....	3,293	3,240
September	....	1,492	1,597
Total	1,759	13,560	15,588

Considering the Gird Creek ditches and the Skalkaho canal together gives the following statement of duty for 1903:

Duty of water under Gird Creek ditches and Skalkaho ditch for 1903.

Area irrigated	acres..	3,320
Water used	acre-feet..	28,218
Depth over surface	feet..	8.50

WARD CANAL.

The Ward canal diverts water from Skalkaho Creek, a tributary of the Bitter Root. It is the third in elevation of the five canals operated by the Ravalli Land and Irrigation Company. It is 7 miles long, has a capacity of about 70 cubic feet per second, and waters 3,985 acres. The areas devoted to the various crops in 1903, so far as could be learned, were as follows:

Acreage of crops irrigated under Ward canal in 1903.

	Acres.
Meadow	849
Oats	573.3
Wheat	102
Roots and vegetables	14.8
Orchards	33
Pasture	383.6

The monthly discharges and the depths on the land are given in the following table:

Discharge of the Ward canal for 1901, 1902, and 1903.

Month.	1901.		1902.		1903.	
	Discharge.	Depth.	Discharge.	Depth.	Discharge.	Depth.
	Acre-feet.	*Feet.*	*Acre-feet.*	*Feet.*	*Acre-feet.*	*Feet.*
April	591	0.16	230	0.06	....	....
May	3,009	.84	2,318	.58	1,852	0.46
June	2,529	.71	3,752	.94	4,424	1.11
July	2,059	.57	2,566	.65	2,771	.70
August	438	.12	807	.20	844	.21
September	....	....	253	.06	345	.09
Total	8,626	2.40	9,926	2.49	10,236	2.57

Figure 14 shows the use of water under the Ward canal in 1903.

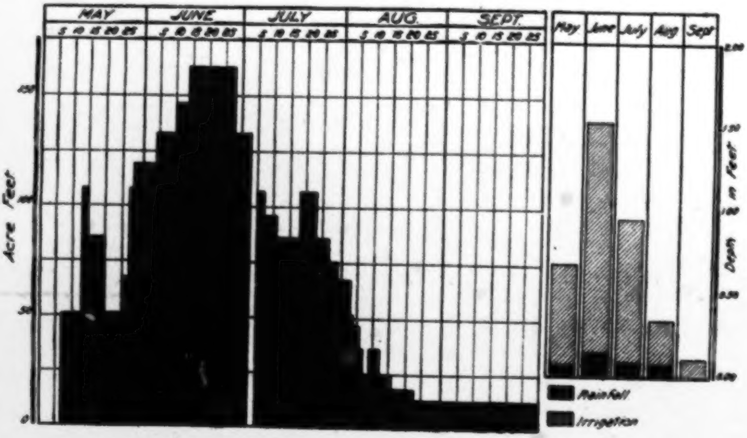

FIG. 14.—Daily discharge of Ward canal, 1903, and depth of water received by land.

HEDGE CANAL.

The Hedge canal diverts water from the Bitter Root River about 35 miles above the Republican canal. The original ditch of this name was built by Mr. Hedge for the purpose of diverting water from Skalkaho Creek, but Mr. Daly, after purchasing the rights of Mr. Hedge, extended the canal up the valley by means of flumes to tap the Bitter Root. There are about 5 miles of flumes on this canal, and two ravines are crossed by means of redwood-stave pipe laid in the form of an inverted siphon. This canal is 24 miles long, has a capacity of over 200 acre-feet per day, and waters over 5,000 acres. The areas irrigated in 1901, 1902, and 1903 were 5,260 acres, 5,420 acres, and 5,420 acres, respectively.

The results of surveys made in 1903 to determine the areas under this canal which were devoted to particular crops are included in the table given below.

Acreage of crops irrigated under Hedge canal in 1903.

	Acres.
Meadow	1,267
Oats	549
Wheat	83
Roots and vegetables	9.6
Orchards	58.5
Pasture	463
Total	2,430.1

The monthly discharge of the canal and the depths to which it would cover the land served are given in the following table:

Duty of water under Hedge canal for 1901, 1902, and 1903.

Month.	1901.		1902.		1903.	
	Discharge.	Depth.	Discharge.	Depth.	Discharge.	Depth.
	Acre-feet.	*Feet.*	*Acre-feet.*	*Feet.*	*Acre-feet.*	*Feet.*
April	2,194	0.42	1,722	0.32		
May	4,431	.84	5,439	1.00	2,514	0.46
June	3,302	.63	6,243	1.15	6,249	1.15
July	5,573	1.06	5,955	1.10	4,120	.76
August	5,382	1.02	6,277	1.16	4,744	.88
September			6,626	1.04	5,183	.96
Total	20,882	3.97	31,262	5.77	22,810	4.21

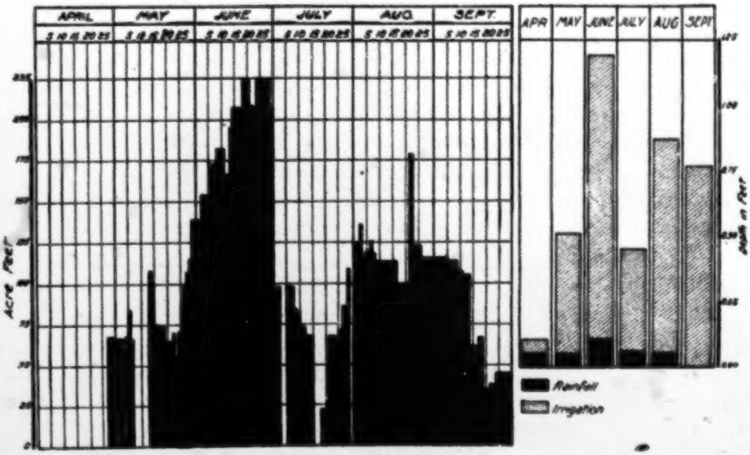

FIG. 15.—Daily discharge of Hedge canal, 1903, and depth of water received by land.

Figure 15 illustrates the use of water under the Hedge canal in 1903.

Until the year 1903 all the experiments on the duty of water in the Bitter Root Valley were conducted on the Bitter Root stock farm. This tract occupies the middle portion of the valley. In order to obtain a fair test for the entire valley three other tracts of land were selected in other sections of the valley.

HARLAN DITCH.

The Harlan ditch diverts water from the Bitter Root River near the Como bridge and carries water to the farm of Mr. W. B. Harlan. This farm consists of a gravel and sand wash from a canyon entering the valley from the east. The area irrigated was 83 acres. The water was measured near the upper end and a small loss was sustained in transmission and 25 per cent was wasted at the lower side of the farm. The discharges given below are 25 per cent less than those shown by the measurements:

Duty of water under W. B. Harlan's ditch for the season of 1903.

Month.	Discharge.	Depth.
	Acre-feet.	*Feet.*
May	170	2.05
June	232	2.80
July	162	1.95
August	92	1.11
Total	656	7.91

BASS BROTHERS' DITCH.

Bass Brothers' ditch diverts water from a small stream of the same name which is a tributary of the Bitter Root River. This ditch irrigates about 400 acres of very fertile land on the west side of the Bitter Root River about 5 miles northwest from Stevensville. The soil of this farm is a compound of decomposed granite and vegetation, with some sand and gravel. It is about 2 feet deep and slopes quite rapidly toward the middle of the valley.

On May 26, 1903, a rating flume was placed in the ditch as it enters the field. The record of gauge height was kept by an automatic register. There were no seepage losses of noticeable quantity. The monthly discharge and the depth of irrigation are given in the following table:

Duty of water under Bass Brothers' ditch for the season of 1903.

Month.	Discharge.	Depth.
	Acre-feet.	*Feet.*
May	67.76	0.169
June	254.63	.636
July	156.70	.392
August	118.61	.296
Total	597.70	1.490

The areas in the various crops were as follows:

Acreage of crops irrigated under Bass Brothers' ditch for the season of 1903.

	Acres.
Timothy and clover	175
Orchard	85
Wheat	30
Oats	10
Peas and garden	10
Pasture	90
Total	400

Figure 16 illustrates the use of water under Bass Brothers' ditch in 1903.

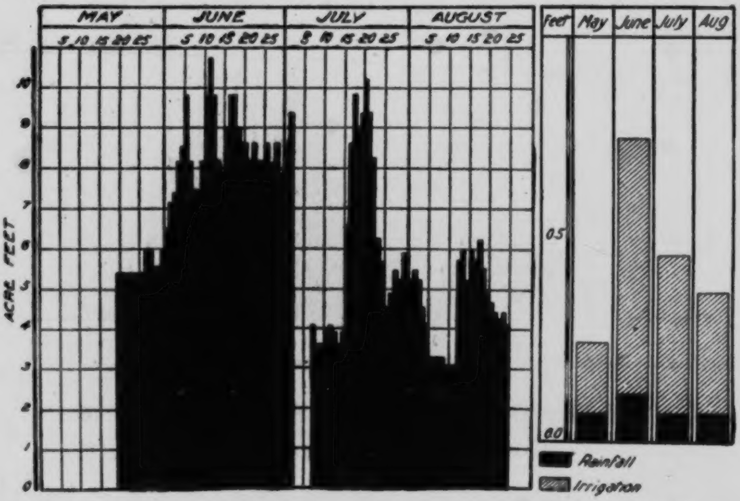

FIG. 16.—Daily discharge of Bass Brothers ditch, 1903, and depth of water received by land.

ALLEN, HUGHES, ET AL. DITCH.

This ditch takes its waters from Lolo Creek near the mouth of the Bitter Root Valley, and on the west side of the river. The land covered is a delta or wash from the Lolo Canyon, and is composed of a gravel and sandy loam underlaid by a deep bed of gravel. This drinks up the water rapidly, and the ground is solid and firm in a very short time after the irrigation. The climate and soil in this locality are particularly well adapted to fruit growing, and all the varieties of apples, pears, plums, and berries, with some very fine peaches, grow well. On May 28, 1903, a rating flume with automatic register was placed in the ditch at the upper edge of the field and there was no loss by seepage. The area watered was 247.6 acres.

The monthly discharge and the depth are given in the following table (fig. 17):

Duty of water under Allen, Hughes, et al. ditch for season of 1903.

Month.	Discharge.	Depth.
	Acre-feet.	*Feet.*
May	20.62	0.08
June	611.60	2.46
July	344.92	1.39
August	613.68	2.47
Total	1,590.82	6.40

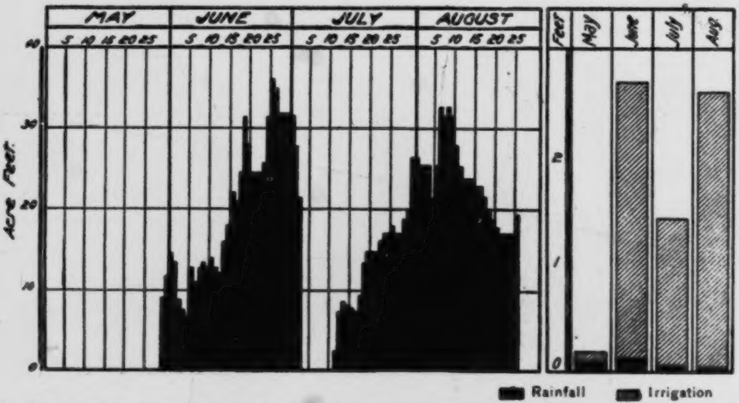

FIG. 17.—Daily discharge of Allen, Hughes, et al. ditch, 1903, and depth of water received by land.

The following table shows the acreage of different crops:

Acreage of crops irrigated under Allen, Hughes, et al. ditch in the season of 1903.

	Acres.
Orchard	91.6
Clover	76.5
Timothy	51
Oats	20
Garden	5
Potatoes	1.5
Corn	1
Beets	1
Total	247.6

All measurements of depth of water to which the water diverted by canals would cover the land irrigated by them, disregarding losses in transit are brought together in the following table:

Summary of the duty of water measurements in Montana.

County.	Canal.	Year.	Depth.
			Feet.
Gallatin	West Gallatin high line	1902	5.32
Do	Kughen or Cameron	1902	4.68
Do	do	1903	5.78
Do	Weaver & Stone	1902	5.56
Do	Middle Creek canal	1899	2.10
		1900	1.90
		1901	2.33
		1902	1.15
		1903	1.48
Do	Middle Creek (all canals)	1902	2.60
Do	West Gallatin Irrigation Co	1902	5.32
Yellowstone	Big ditch	1901	2.56
		1902	3.68
		1903	4.12
Ravalli	Republican	1901	3.35
		1902	4.51
		1903	2.95
Do	Skalkaho	1901	4.68
		1902	6.82
		1903	6.31
Do	Gird Creek and Skalkaho	1903	8.50
Do	Ward	1901	2.40
		1902	2.49
		1903	2.57
Do	Hedge	1901	3.97
		1902	5.77
		1903	4.21
Do	Harlan	1903	7.91
Do	Bass Brothers	1903	1.49
Do	Allen, Hughes, et al	1903	6.40
	Average		4.10

DUTY OF WATER IN COURT DECREES IN MONTANA.

Since the rights to the use of water can be determined only by the courts as the result of litigation, and since water is the chief factor in the agricultural development of the State, it may add to the value of this report to review some of the decisions of these tribunals in which parties have been granted rights to the use of fixed volumes of water from the public streams. Only a small percentage of the total number of people who use water have had their rights thus defined, but in every county where irrigation has been practiced for some time controversies over water have arisen and the majority of these controversies have culminated in court decisions which are on file in the recording offices of the respective counties. Some of these decisions are so indefinite as to possess little, if any, value in a discussion of this character. One party, for example, may be decreed a certain number of miner's inches of water from a particular stream without reference to the extent or location of the land which such water is intended to irrigate. To another party may be decreed a certain fraction of all the flow of a creek with or without reference to the area which such fractional part may irrigate. It is only where a definite number of miner's inches have been decreed to a stated number of acres that use has been made of the decisions in compiling the following tables:

Duty of water in court decisions in Montana.

Name of stream.	Date of decree.	Miner's inches of water.	Acres of land.
Carbon County:			
Sage Creek	Jan. 7, 1901	565	495
Cole Creek	Mar. 14, 1902	720	720
Red Lodge Creek	July 21, 1904	6,683	6,683
Rocky Fork Creek	Aug. 21, 1903	51,916	51,886
Blue Water Creek	Feb. 29, 1904	2,466	2,466
Total		62,350	62,250
Ravalli County:			
Eight Mile Creek	May 27, 1897	930	1,353
Lost Horse Creek	June 14, 1898	39	160
Barnaby Creek	Oct. 17, 1898	302	480
Larry Creek	do	257	280
Mill Creek	Mar. 9, 1903	2,993	4,249
Fred Burr Creek	Mar. 10, 1904	3,069	5,713
Sleeping Child Creek	Mar. 3, 1904	640	620
Total		8,230	12,855
Gallatin County—East Gallatin River	Apr. 2, 1892	2,614	2,623
Missoula County:			
Carlton Creek	Feb. 21, 1902	1,957	3,477
Rattlesnake Creek	July 9, 1903	1,803	3,869
Total		3,760	7,346
Sweet Grass County:			
Bridger Creek	Mar. 18, 1898	455	880
Spring Creek	Nov. 17, 1899	300	320
Big Boulder River	Feb. 16, 1901	400	320
Do	Feb. 19, 1901	700	625
Duck Creek	do	450	1,400
Otter Creek	June 25, 1903	675	1,440
Duck Creek	do	2,386	6,032
Total		5,366	11,017

These summaries show that 82,320 miner's inches of water have been decreed to irrigate 96,091 acres of land, or at the rate of 1 miner's inch to 1.17 acres. In Carbon County during the past three years 62,350 miner's inches have been granted for the purpose of irrigating 62,250 acres, or slightly more than 1 miner's inch per acre, or 1 cubic foot per second for each 40-acre tract. This would require a continuous flow for about eighty-two days to supply a depth of 4.1 feet, the average of all the measurements reported in the preceding pages. The court decrees, therefore, correspond approximately to general practice.

SEEPAGE AND RETURN WATERS.

Unfortunately, most canals lose in transit large quantities of water, varying from 10 to 60 per cent of the amount diverted. A part of these losses frequently returns to the same stream either on the surface or through subsurface strata, and is diverted by other canals located at lower levels.

In irrigated valleys the first, second, and third benches, which extend upward like terraces from a stream, are usually watered by one or more canals on each bench. In other instances the irrigated lands occupy a plane which rises with a uniform grade from the bank of the stream. In both cases the canal, which is located next to the highest in a series, receives a large part of the water which percolates from the one above it and in turn transfers a part of its flow to the next lower.

The water supply of irrigated districts is still further influenced by seepage water from irrigated areas. Only a part of the water which is spread over the soil is utilized by the plants. The balance is either evaporated from the surface or percolates slowly through the subsoil. When porous bench lands are heavily irrigated a portion of what sinks beneath the surface returns to the river channels and augments to a considerable extent the available flow.

A knowledge of the quantities of water lost from canals and draining from irrigated lands and collected by other canals, or returning to the stream to be rediverted, is of great importance to courts in the adjudication of rights, and to administrative officials in the distribution of water from streams.

Seepage waters have likewise to be considered in providing for drainage. It would be wrong to conclude that the seepage losses from canals always return to the channel of the stream or were intercepted by other canals. Waste water of this kind quite frequently gravitates to the lower levels of an irrigated district and makes unproductive marshes and alkali flats of what otherwise might have been fertile fields. It is important to determine the extent of this loss in order to plan the size, number, and direction of the drains, and to endeavor to intercept the waste water before it reaches the lower levels.

Seepage from earthen canals represents the greatest loss of irrigation water, and until the amount is approximately ascertained for each canal it is not probable that any steps will be taken to lessen this loss.

LOSSES IN CONVEYANCE OF WATER.

The principal losses which occur in conveying water from a stream or other source of supply to the place of use may be grouped under one or the other of three heads. These are leakage, evaporation, and percolation.

LEAKAGE.

The loss due to leakage is readily traceable to faulty construction and can be remedied only by better structures and the exercise of higher skill in the building of canals. The wooden flumes to be found on nearly every canal are the chief source of leakage. Some leak so badly as to endanger their safety. This can be remedied by using a better grade of lumber and building the flumes in such a way as to insure water tightness. In many cases the best course to take with an old wooden flume is to substitute for it something more permanent. This has been done by the officers of the Big ditch in Yellowstone County. When this canal was first built many wooden flumes were used to cross depressions. In time these structures decayed, but instead of having them replaced the superintendent built earthen embankments on each side. These carried water more efficiently and were permanent structures, thus lessening the annual cost of maintenance.

Leaks are sometimes caused by the shattering of rock or other material by blasting during construction, or by failing to provide impervious connections between canal embankments and the original surface. Another source of loss is leaky gates. A slight leakage from the closed head gate of a farmer's lateral is a trivial matter, but the combined loss from a score or more of badly fitting gates may amount to a considerable volume of water.

LOSS OF WATER BY EVAPORATION.

The principal loss of water by evaporation occurs after the water is spread over a field and not while it is being conducted in canals. During the early part of the irrigation season in Montana the temperature of water in canals is quite low, often between 50° and 60° F., and the evaporation in consequence is low.

The basis for computing the loss of water by evaporation from ditches and canals has been the evaporation from a standard tank at Bozeman. The records for the irrigation season extending from May 1 to September 30 of each year, from 1900 to 1903, are given in the following table:

Evaporation from water surface at Bozeman, Mont. (in inches).

	May.	June.	July.	August.	September.	Mean.
1900.						
Mean temperature of water	....	73° F.	....	....	55° F.	64° F.
Monthly evaporation	5.52	5.99	3.59	3.88	2.74	4.34
Average weekly evaporation	1.24	1.39	0.80	0.88	0.63	0.99
1901.						
Mean temperature of water	59° F.	60° F.	68° F.	69° F.	56° F.	62° F.
Monthly evaporation	5.27	4.20	4.34	5.27	3.43	4.30
Average weekly evaporation	1.19	0.98	0.98	1.19	0.80	1.03
1902.						
Mean temperature of water	54° F.	67° F.	65° F.	65° F.	54° F.	61° F.
Monthly evaporation	3.40	3.30	4.07	3.60	3.01	3.49
Average weekly evaporation	0.77	0.77	0.92	0.81	0.70	0.79
1903.						
Mean temperature of water	61° F.	62° F.	64° F.	67.6° F.	68° F.	64.5° F.
Monthly evaporation	[a]1.12	3.99	3.90	3.38	3.36	....
Average weekly evaporation	0.60	0.93	0.88	0.76	0.78	0.79

[a] May 19-31.

Taking the results as given in the preceding table, the average weekly evaporation from May 1 to September 30, of a four-year period, amounts to a trifle more than 0.9 inch per week. This figure has been taken to compute the loss of water by evaporation from typical canals. The following table gives the results of such computations for ten canals:

Amount of water evaporated from typical canals in Montana.

Number of canal.	Discharge.		Width of surface.	Evaporated per mile of canal.
	Cu. ft. per second.	*Miner's inches.*	*Feet.*	*Miner's inches.*
1	6	240	5	0.13
2	12	480	6	.15
3	25	1,000	9	.23
4	40	1,600	12	.31
5	70	2,800	20	.52
6	110	4,400	25	.65
7	200	8,000	31	.81
8	300	12,000	40	1.04
9	400	16,000	47	1.22
10	600	24,000	58	1.51

It has been considered desirable to give a reasonably close estimate of the loss by evaporation from typical canals in order to correct a false idea which is prevalent regarding it. It is not unusual for irrigators to hold that the greater part of the losses which occur between the intake and their fields is due to evaporation instead of to seepage. Now, the computations show that this loss, even in large canals, is not worth reckoning with. A canal, for example, 12 feet wide on top and carrying 1,600 miner's inches, loses less than a third of a miner's inch per mile, while one 40 feet wide and carrying 12,000 miner's inches loses a trifle more than 1 miner's inch.

SEEPAGE.

In the measurements that have been made to determine the losses in the transportation of water for irrigation purposes few attempts have been made to separate the volumes lost in different ways. It has been previously shown that the amount evaporated is small in comparison with the total loss. In canals that are skillfully maintained and operated the loss due to leaks is likewise small. It is apparent, therefore, that by far the greatest loss arises from percolation or seepage. The results given in the table which follows include loss from all sources, the greater part of which is, as just stated, from seepage. The canals tested were usually representative of the larger class in the district. After one had been selected the necessary arrangements were made with the superintendent before the date fixed for the beginning of the test. A gauge rod of some kind was inserted near the intake, and the discharge ascertained by means of a current meter. The person in charge of the head gates was then instructed to hold the water at the same height during the subsequent measurements. The field party then traveled down the canal, measuring each diversion and each inflow as they passed it. At some suitable point on the canal, preferably at a road crossing, the canal was measured a second time. The difference between these measurements, provided there were neither diversions nor inflows, represented the losses in transit between the points of measurement. In case there were diversions through laterals and inflows from creeks or other sources the canal was debited or credited, as the case might be, with the respective amounts. All measurements of main canals were made with current meters in the customary way, but the methods used in the measurement of laterals depended somewhat on the accuracy of the measuring devices belonging to each canal. As a rule all lateral diversions were measured over weirs or with current meters.

The results of all such measurements made are summarized in the following table:

Losses from canals by seepage and evaporation.

Name.	Date.	Length measured.	Flow at upper end.	Loss.	
				Cubic feet per second.	Per cent.
Yellowstone Valley:		*Miles.*	*Cu. ft. per second.*		
Big ditch	August 9-13, 1900	22.00	254.47	65.05	25.56
Do	June 10-13, 1902	33.90	310.77	47.11	15.16
Do	August 4-6, 1902	30.40	300.65	29.07	9.25
Do	1903	28.86	382.92	12.20	3.19
High Line canal	do	18.51	75.20	20.34	19.29
Yellowstone ditch	do	7.00	35.60	6.89	19.35
Italian ditch	do	9.62	50.60	−2.70	−5.04
Canyon Creek ditch	do	12.00	59.72	10.76	18.02
Mill ditch	do	8.00	29.33	1.78	6.07
Flaherty Flat ditch	do	3.00	21.28	−1.17	5.25
Merrill ditch	do	8.25	30.81	5.26	17.07
Gallatin Valley:					
West Gallatin Irrigation Company	July 18-20, 1900	38.75	114.45	39.06	34.13
Do	June 24-25, 1902	26.50	93.67	26.31	26.66
Do	1903	23.25	70.08	18.80	26.82
Cameron ditch	do	7.82	26.48	7.60	28.17
Farmers' canal	1900	10.75	133.10	23.59	17.65
Kleinschmidt	1903	17.50	96.11	10.24	9.65
Bitter Root Valley:					
Republican canal	1900	11.60	120.49	35.35	29.34
Do	1902	12.00	65.52	18.16	27.71
Do	1903	5.25	88.11	6.83	7.75
Do	do	9.75	76.46	6.09	7.96
Hedge canal	1902	17.75	80.83	16.08	19.90
Do	1903	17.50	99.96	3.24	3.08
Ward ditch	1902	7.40	55.32	2.00	3.62
Do	1903	8.00	35.09	7.82	20.53
Skalkaho ditch	1902	5.96	37.92	5.07	13.39
Do	July, 1903	5.50	29.32	3.09	10.54
Do	August, 1903	5.50	32.58	1.18	3.62
Surprise ditch	1902	5.00	51.20	18.61	30.84
Supply canal	do	14.00	60.90	40.56	66.60
Allen, Hughes, et al	1903	1.25	8.32	1.80	21.63
Fowler and Sistah ditch	do	3.00	7.23	1.61	22.27
Union ditch	do	6.00	36.49	3.13	8.26
Average					18.22

It should be borne in mind that the loss shown in the above table is the net loss, as most canals receive more or less inflow from above. In one case this was so great that the canal showed a net gain. Again, the portions of the canals measured represent only a part of the total loss by seepage in the conveyance of water from the natural stream to the irrigated fields. No attempt was made to determine the losses in the network of laterals which take the water to the boundaries of the fields.

The effect produced on the flow of a canal by the inflow of seepage from another and higher canal, and the land which it irrigates, is well illustrated by the Big ditch. August 9–13, 1900, there was a total loss on this canal from Tilden's ranch to Hesper farm, a distance of 22 miles, of 65 cubic feet per second, or 25.56 per cent of the total flow. In the following year water was turned into a new branch of this same canal known as the High Line, and the seepage from this new branch and from the irrigated farms under it produced a noticeable change in the flow of the main canal. In June, 1902, there was sufficient inflow from the High Line canal to reduce the seepage losses in the main canal to 47.11 cubic feet per second in 33.9 miles, or a total net loss of only 15.16 per cent. In August of the same year a second series of measurements was made and the total loss was but 9.25 per cent in 30.4 miles. The results of measurements made on the same canal in the summer of 1903 show that a still larger quantity of seepage water was admitted from the upper canals which included not only the High Line, but also the Yellowstone canal.

The Yellowstone ditch and also the High Line canal are located at higher elevations than the Big ditch, and it is presumed that a part of the water which escaped from these channels was intercepted by the Big ditch. However, since the combined loss from the channels was 27.23 cubic feet per second this alone would not suffice to produce the change previously mentioned in the Big ditch. The balance must have come from irrigated farms.

The measurements of the Italian and Canyon Creek ditches of Yellowstone Valley show that there is a large flow into both ditches. This is readily accounted for by the fact that there are canals and irrigated areas above each.

There was a large increase in the Mill ditch in the third and fourth miles from the head, which would appear to indicate the admission of a tributary, but the increase was wholly due to seepage water.

The results of measurements made on the West Gallatin irrigation canal during 1900, 1902, and 1903 differ from those of the Big ditch in Yellowstone Valley in that the former show a somewhat fixed régime. This condition is readily accounted for. There are no canals located on higher ground, and consequently no irrigated areas from which waste water might drain into the canal. In 1900 the loss from the entire canal, including Camp Creek lateral, was about one-third of the volume admitted. The tests made in 1902 and 1903 were each made by different parties, and frequently different gauging stations were selected from those used in 1900. Notwithstanding this difference in many of the sections into which the canal was divided, the results obtained in the three years show that conditions have not been materially altered in a four-year period.

Middle Creek canal consists of a main canal something over 4 miles long, and two branches known as North and East forks. Four tests made from 1899 to 1902 show that under ordinary heads the seepage loss in the main canal averages about 20 per cent of the volume admitted. In the North Fork there is a gain—that is, the waste water which flows into it from adjacent irrigated farms more than counterbalances the losses due to percolation in the channel. This gain of 20 to 30 per cent in the North Fork reduces the loss over the entire system to about 16 per cent of the flow through the head gate.

In the Cameron or Kughen ditch the total loss, which does not appear to have been reduced by the inflow of seepage, is 28.7 per cent of the volume admitted. As has been stated in connection with other canals, this is not the actual loss by seepage from this canal, but rather the net loss, which is the actual loss diminished by the amount of inflow. The seepage inflow into the Kleinschmidt canal is derived from creek channels and narrow irrigated valleys.

In 1900, when the first seepage measurements were made on the Republican canal, there was a heavy loss in the upper portion of the canal. On July 21, 1900, out of a total of 120.49 cubic feet per second admitted through the head gate, 35.35 cubic feet per second was lost by percolation before the canal passed Grantsdale, 3.6 miles below the head. The loss in a distance of about 10 miles below this upper section was counterbalanced by seepage waters from irrigated areas above the Republican canal. The results for 1902 show that the net loss has been reduced by the interception and admission of percolating waters from the Hedge canal, immediately above the Republican. In 1903 only the upper portion of the canal was tested, but the results show a still further diminution in the net loss by seepage. In 1 mile there is a gain of 2.97 cubic feet per second, showing that sufficient percolating water from higher elevations was admitted not only to make up for the loss but to produce a surplus.

The results of seepage measurements made throughout the entire length of the Hedge canal in 1902 and also in 1903 show that conditions are changing. In 1902, 16.08 out of 80.83 cubic feet per second admitted was lost. If earlier measurements had been made they would probably have shown that this loss of 19.9 per cent was not the total loss, because in 1903 it is found that out of nearly 100 cubic feet per second admitted there is only a net loss of 3 per cent. In a distance of 2 miles there is a gain of 5.24 cubic feet per second, derived from the seepage waters of Skalkaho Creek, and in other sections there are large gains derived from waste waters from irrigated farms.

It is likewise evident from the figures given in the table that the Ward canal has no fixed régime. The net loss arising from seepage seems to depend on the amount of water which percolates from higher ground and which is intercepted by this canal.

There is less fluctuation in the net flow of the Skalkaho canal, due, doubtless, to the fact that in more than one-half of its length it flows through a flume which is practically water-tight.

THE EFFECT OF SEEPAGE AND RETURN WATERS IN AUGMENTING THE FLOW OF STREAMS.

During the summer of 1903 a series of measurements to determine the gain due to seepage was made on the Bitter Root River.

That part of the Bitter Root River which was included in the investigation extends from Grantsdale highway bridge to the Buckhouse bridge, a distance of 48 miles, and includes the bulk of the irrigated area of the Bitter Root Valley in a north-and-south direction. The arable and irrigable lands in an east-and-west direction average about 10 miles in width over this same length.

The first series of measurements was made from June 11 to 15, 1903, and consisted of a measurement of the river at Grantsdale and a measurement of each of 39 tributaries, as well as five diversions through irrigation canals. The results of the first series of measurements, expressed in cubic feet per second, are as follows:

Return seepage, Bitter Root River, June 11-15, 1903.

Discharge of river at Grantsdale, Mont	9,111.3	
Inflow from 39 tributaries	5,764.2	
Total inflow		14,875.5
Discharge from river at Buckhouse bridge	12,660.6	
Diversions through canals	313.5	
		12,974.1
Loss in 48 miles		1,901.4

The second series was made about a month later, between July 9 and 14, after the spring floods had subsided. The results of the second series of measurement, expressed in cubic feet per second, are as follows:

Return seepage, Bitter Root River, July 9–14, 1903.

Discharge of river at Grantsdale, Mont	2,320.9	
Inflow from tributaries	1,623.8	
Total inflow		3,944.7
Discharge of river at Buckhouse bridge	4,221.7	
Diversions through canals	161.7	
Total outflow		4,383.4
Gain in 48 miles		438.7

The third series was made from August 7 to 14, at a time when the discharge of the river and the various tributaries was quite low. The results of the third series of measurement, expressed as before, are as follows:

Return seepage, Bitter Root River, August 7–14, 1903.

Discharge of river at Grantsdale, Mont	325.5	
Inflow from tributaries	209.5	
Total inflow		535.0
Discharge of river at Buckhouse bridge	1,536.8	
Diversions through canals	111.8	
Total outflow		1,648.6
Gain in 48 miles		1,113.6

The foregoing figures show that a large volume is held back during the flood period, when all the natural channels are full, and that much of the water which is temporarily stored in this way returns to the channel of the river to augment the flow during the latter part of the season. According to the measurements, a volume of 1,901 cubic feet per second was retained on June 11–15. The only way to account for this loss is by infiltration in the soils and subsoils of the valley. It is probable this process went on over about 480 square miles of open, gravelly soil, and if this is so it is not surprising that a stream of nearly 4 cubic feet per second on an average should be absorbed by each section of land. This process of absorption or infiltration of water, if one considers the entire area affected, terminated about July 6. After this date there is a gain instead of a loss. This gain is small at first, but at the end of thirty-seven days increases to 1,113 cubic feet per second. The conditions found between August 7 to 14 are remarkable. The total discharge of the stream at Grantsdale is only 325.5 and that of all the tributaries 209.5, or 535 cubic feet per second in all. At the same time there is an available flow of 1,648.6 cubic feet per second at a point 48 miles farther down the stream. In other words, the increase is more than double the ordinary flow of the stream.

It is not to be inferred that this increase was derived wholly from return waters which were for a time absorbed in the subsoil of 480 square miles of porous lands. A large part was undoubtedly due to seepage losses from the irrigated farms in the same valley.

That the conditions which obtained on Bitter Root River in 1903 are not unusual is evidenced by similar conditions which have been shown to exist on other western streams.[a]

CONCLUSIONS AND RECOMMENDATIONS.

WASTE OF WATER.

According to the author's estimate, the total area that is ever likely to be irrigated in Montana from streams, reservoirs, and wells will not exceed 6,000,000 acres, while the fertile and arable land that might be irrigated may comprise three times this area. The reason for this low estimate is the smallness of the water supply, the short period of plant growth, and the fact that the large tracts of irrigable land are not always accessible to the large streams. This estimate was based on an average supply of 2 acre-feet of water for each acre of land, which may be regarded as the minimum quantity required under the most economical use which is to be expected.

The average quantity diverted per acre irrigated, as shown by the measurements reported in the preceding pages, is 4.1 acre-feet, or more than twice the quantity used in the estimate (see p. 7). In so far as rights have been adjudicated, the courts have confirmed rights to this quantity (see p. 84).

The difference between these quantities represents the possible extension of the irrigated area in Montana, after the streams are exhausted under present practice. The measurements of return seepage (see p. 91) show that at least a part of this water drains back to the streams, to be used again, but undoubtedly a large part of this excess is lost by evaporation when spread over the ground, and by percolation into substrata which does not drain back into the surface streams. Further, the water thus wasted is likely to injure either the land to which it is applied or that lying below. This necessitates drainage to protect land against water-logging and alkali. The two great sources of loss are poorly constructed ditches and careless irrigation.

POORLY CONSTRUCTED DITCHES.

Middle Creek canal, in Gallatin County, may serve as an illustration of the waste of water in ditches. It was begun in 1871 by a small association of farmers who had neither sufficient means nor the necessary equipment to build a good canal. The ditch was located with a spirit level fastened to a tripod. Each stockholder was required to provide a certain number of men and ox teams and to perform an amount of labor proportionate to the number of shares of stock which he owned. Thus this badly located canal was built at odd times in a sort of haphazard way. Questions of grade, of suitable materials, or of loss by percolation did not worry these farmers; their main object was to get water to their ranches, and if a few plow furrows served their purpose they were content.

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[a] See U. S. Dept. Agr., Office of Experiment Stations Bul. 158.

Under the conditions which then existed the members of this pioneer cooperative association may have pursued the proper course. Water was then cheap and fairly plentiful, the new settlers were poor, and it might have been unwise to spend more money on the canal at that time. But many of the first settlers have since become well to do; land has quadrupled in value, and water is both valuable and difficult to obtain. Of former landmarks, the old ditch has changed least. Few improvements have been made, the water still ripples over the cobbles in the bed, the head gates are taxed to resist the spring floods, the farmers' head gates are crumbling to pieces, and the distributing ditch is cutting each season a deeper gully in the cultivated field. But worst of all, nothing has been done to lessen the waste of water by percolation. For every 5 cubic feet of water taken out of the creek 1 is wasted before this volume has flowed 4 miles.

Some canals show even larger losses. The measurements made show losses of over 30 per cent in a single mile, while the average loss for all canal measurements reported is 18.22 per cent (see p. 88). While it is impossible to prevent all these losses, great improvements can be made at small expense.

As the demand for water increases these conditions will tend to be corrected, but the practice of the courts of decreeing rights to enough water to supply land after a large part of it has been lost in transit will not tend to correct this evil. If a man is granted sufficient water for his land under economical use, and this quantity is measured to him at the head of his ditch, he will make every effort to stop losses which leave him without water enough for his land. This has been done in Nebraska. The law fixes the limit at 1 cubic foot of water per second for 70 acres, and the State supreme court has held that the measurement must be made at the head of the ditch. The State certainly has a right to insist upon an economical use of its resources.

CARELESS IRRIGATION.

Where irrigated farms are large and skilled labor difficult to secure, the tendency is to crop a larger area than can be properly cared for. The average Montana farmer likes to have a large acreage in crops. His fields, as a rule, are well plowed and harrowed, but having performed these necessary preliminary operations and drilled in sufficient seed, he pays little attention to the condition of the surface for rapid and efficient irrigation. More care in this regard would pay well. If the surface is once carefully graded and the ditches located and built in such a manner as to meet the local requirements, a forage crop like alfalfa may be grown for ten successive years with little additional outlay. The same is practically true of a grain crop. Even with a hoed crop like potatoes or sugar beets, it is an easy task to reduce the surface to a uniform grade before the next crop is seeded.

The surface of the average irrigated land can be put in reasonably good condition for irrigation for $5 per acre, but to be safe it is here assumed that the cost is $7.50. This principal at 12 per cent would yield a revenue of 90 cents a year, and represents the difference between a rough, uneven surface and a smooth, graded surface. In the case of alfalfa, which is cut three times, this annual interest would amount to 30 cents per acre for each crop. The labor of irrigating the properly prepared field is much less, there is a saving of water, the soil is not damaged, there is considerable increase in the yield, and the quality of the crop is improved. Taking all this into consideration, an expenditure of $7.50 per acre would return 60 instead of 12 per cent. While only one crop is harvested in a year, the advantages of a carefully graded field would need to be worth 90 cents per acre a year, but there are few practical irrigators who would not admit that the extra quality of the yield would more than compensate for this outlay.

RIGHTS TO THE USE OF WATER SHOULD BE DEFINED AND ESTABLISHED.

Of the 1,500,000 acres irrigated in Montana only a small percentage has a well-defined and clearly established water right. In all probability the adjudicated rights to the use of water do not cover more than one-tenth of the total irrigated area.

The records pertaining to the appropriation of water, as filed in the recorder's offices of the respective counties, possesses little value, for the reason that the majority of claims filed do not represent accurately the plans of the claimants and there is no means of ascertaining from the records themselves which plans have been perfected and which have been abandoned.

No definite or accurate information can be obtained from county or State records regarding the volumes which are appropriated from any stream or the volumes carried by irrigating ditches or the extent of the land which each ditch waters.

With few rights determined, and with little provision for the equitable distribution of water according to priorities, it is not surprising that waste, illegal diversions, and unjust allotments should prevail. Unjust distribution of water and failure to obtain it at the right time greatly affect the annual yields. Again, there is the time and labor lost in striving to protect one's rights; one man irrigates while another patrols the ditch. This common property, so valuable to the farmer, is not controlled by either the State or the nation, and men quarrel over it well-nigh continuously throughout the season. The division of water is the chief topic discussed in farm homes from seed time to harvest, and communities seem willing to spend the greater part of their earnings in protracted litigation.

As has been stated, the waste of water, which is the greatest evil in Montana irrigation practice, will tend to correct itself as the demand for water increases, but the evils arising from undefined rights and the lack of public supervision of distribution will grow with the demand for water and greatly limit future development. These are matters which can be corrected only by proper legislation.

In the opinion of the writer, some of the essential features of the irrigation legislation needed by the State of Montana are as follows:

(1) To declare:

(*a*) That the waters of the State shall be subject to appropriation for beneficial use: *Provided*, That no water can be legally diverted which is not put to a beneficial use.

(*b*) That rights to water for irrigation shall be appurtenant to definite tracts of land, specified in the applications and permits on which the rights are based, except that rights can be transferred to other tracts, or used for other purposes, where such transfer or change in use does not injure holders of other rights or reduce the supply beyond the amount of the water transferred or used for other purposes: *And provided further*, That no transfer or change of use shall be made until approved by the State engineer or the court, after a properly advertised hearing has been given to all interested parties.

(2) To make provision for an early adjudication of rights which have already accrued, thus providing a guide for the distribution of water and for determining the amount of the unappropriated waters.

(3) To provide for the acquirement of rights in the future by application to the State engineer, and the construction of works and use of water after the issuing of a permit by the engineer; the right to be confirmed by the State after satisfactory proof that the conditions of the permit have been fulfilled and the water applied to beneficial use.

(4) To keep a complete record in the office of the State engineer of all perfected rights, applications, and permits.

(5) To divide the State, according to drainage basins, into divisions and districts for administrative purposes.

(6) To provide an administrative system for the equitable distribution of water among those entitled to its use.

TRANSFERS OF WATER RIGHTS.

In recommending that rights to water for irrigation be made appurtenant to the land watered it is not intended to make this provision too rigid. When a tract of land becomes too moist to need water, or when it becomes unprofitable to apply water, it is to the interest of both the owner and the public that the water be used on a more productive tract. But there are two classes of rights that should be guarded, viz, those of neighboring water users and those of the public. The Montana law at present provides that transfers may not be made when the rights of others are injured; but the usual practice is for the transfer to be made, after which anyone claiming to be injured may bring suit to have it stopped. This puts on the one who certainly derives no benefit, and who may be injured, the burden of preventing the transfer. In Idaho the party wishing to make the transfer must make application to the State engineer, who holds a hearing after advertisement of the application and the time and place of the hearing. This places the burden where it belongs—on the party who is to benefit by the transfer. Such a hearing will also enable the State engineer to determine whether the transfer will be detrimental to the public interest.

ADJUDICATION OF EXISTING RIGHTS.

The rights to water which have been acquired should be defined and established. Without this any administrative system is useless, as those charged with distributing water will have nothing to go by, and the State engineer will have no means of knowing whether or not there is surplus water, rights to which may be acquired by applicants. On very few streams have the rights been defined and under the present system, as a rule, rights will not be defined until there is a shortage, and if they should be, rights acquired after an adjudication has taken place will not be included, which will make necessary new adjudications from time to time. If all existing rights are defined and new ones are acquired only under the supervision of the State engineer, this necessity for periodical adjudication will be done away with. For securing a complete list of existing rights the present law has two serious defects. Adjudications will take place only on the initiative of the holders of rights, and if they are indisposed to take the matter up, rights may remain undefined for years. Some way of forcing adjudication is absolutely essential to any orderly public control. Wyoming, Nebraska, Utah, and Nevada have such systems. Those in Utah and Nevada have not been tested in the courts, but the Wyoming and Nebraska laws have been repeatedly upheld by their State courts. Under these laws, State officials make surveys and measurements of the ditches and irrigated lands, and take testimony as to dates of construction and other facts bearing on the dates of acquirement and volume of rights, and on the basis of the surveys and the testimony define the rights. Appeal from such decision to the courts is provided for, but is not generally taken. The second serious defect with the present Montana system is that no provision is made for surveys to secure the facts as to capacities of ditches and areas irrigated. Decisions as to rights which depend entirely on these facts, so far as their volume is concerned, are based entirely on interested testimony. Whether rights are defined by administration officials or by the courts this exact knowledge as to physical facts is essential to just conclusions. In Utah, Idaho, and Oregon rights are defined by the courts, but the law provides for surveys by the State engineer as a part of every adjudication. In Wyoming, Nebraska, and Nevada rights are defined by administrative officers as the basis of such surveys.

This work involves the use of substantial head gates to control diversions and suitable measuring devices to determine the flow. These structures should be inserted by and at the expense of the respective owners under the supervision of the State engineer. As these structures will cost a considerable sum the cost of making the hydrographic survey and the necessary maps and compilations should be paid by the State. The general benefit from this work is surely sufficient to justify the State in bearing this expense.

The additional data required for proper adjudication of rights consist of reliable testimony pertaining to the dates of appropriation of existing rights and accurate information regarding the early use of water from each ditch and the subsequent enlargement, if any. The codes of Western States differ as to the methods of procedure of obtaining these additional facts and of making the final determination of water rights. In Utah the district court appoints from one to three referees; in North Dakota the attorney-general, aided by the district attorneys of the districts affected, bring suit, while in Wyoming the adjudications are made by a board of five State officers, the majority of whom are thoroughly familiar with the character of the stream under consideration, the nature of the diversions, the character of the land irrigated, and the kind of crops grown. The vital point involved is that the settlement of these questions shall be placed in the hands of men having an expert knowledge of canal management and the practical requirements of irrigated agriculture.

ACQUIREMENT OF RIGHTS.

The adjudication of all existing rights will fall far short of its greatest value if it is not accompanied by a provision that in the future rights can be acquired only under such supervision as will insure a public record of their dates and volumes, in order that there may be at all times a complete record of rights. The systems adopted for this in Wyoming, Nebraska, Idaho, Utah, and Nevada are in general the same, and may be considered the best. The person wishing to acquire a water right is required to apply to the State engineer, stating in prescribed form how much water he wants and from what source, the location of his irrigation works, and the lands to be irrigated. If this application is in proper form, and there is unappropriated water in the source of supply, a permit is issued fixing the conditions under which the work must be done and the time when it must be completed. On or before the expiration of this time proof of completion must be submitted, and a certificate is then issued stating what rights have been acquired. Such a system is not intended as a limitation on the acquirement of rights, but rather as a means of encouraging construction by relieving the builders of works of uncertainty as to the water supply and of the necessity of fighting for their rights in the courts.

ADMINISTRATIVE SYSTEM.

The need of competent State officers to divide the flow of canals and streams in a just manner among the water users has been keenly felt in Montana for more than a decade. In 1889 the State legislature, in order to relieve the situation to some extent, provided for the appointment of commissioners by the courts rendering decrees defining water rights on application of the owners of 25 per cent of the rights defined. Many of those whose rights had been established by a decree of the court took advantage of the means provided, but the sphere of action of the law is extremely limited because few rights have been established.

With general provision for the adjudication of existing rights and the orderly acquirement of rights in the future, it would seem best to supersede the present commissioners appointed by the courts by those appointed by the governor under some system that will insure the appointment of men familiar with irrigation practice. In providing for distributing water each drainage basin should be regarded as a unit. A long stream would not be within the jurisdiction of a single court, and some official with a wider jurisdiction than a court commissioner should have charge of the distribution of water from such a stream. In Colorado, Wyoming, Nebraska, Utah, Idaho, and Nevada this has been provided for. Each of these States is divided into divisions on drainage lines in such a way that no stream is in more than one division, and these are divided into districts of convenient size. For each district there is a commissioner who has direct charge of the distribution of water within his district, and for each division there is a superintendent who has general supervision of the work of the commissioners and decides all questions between districts where a stream and its tributaries extend into more than one district.

DUTY OF WATER.

In Montana at least one-fourth of the total available stream flow in summer is now used. In defining the rights which have been acquired no fixed duty can be legally established, since each water-right owner is entitled to the amount of water which he has been accustomed to apply in an economical way.

In the case of rights to be acquired the State has a free hand, and it may place a maximum limit on the amount of water which may be diverted to irrigate a given area of land. In the opinion of the writer this maximum amount should not exceed 3 acre-feet. Fifteen inches of natural rainfall and 36 inches of irrigation water, or 51 inches in all, should be ample for any crop.

In all rights that are hereafter to be acquired the maximum time of use as well as the maximum quantity should be specified. This time limit for summer irrigation might be fixed at five consecutive months. A provision of this kind is necessary in order to utilize to the fullest extent the available water supply. Water is now used in Beaverhead and other counties for winter irrigation. As the area devoted to dry farming is increased the use of water during the early spring and fall months, and even in winter, is destined, it is believed, to increase in a more rapid ratio. It would seem to be well, therefore, to clearly define all kinds of rights to the use of water. One man desires water only during the crop-growing season, which is assumed to be five months; another desires water for winter irrigation, which may be assumed to be for a definite period also; while a third desires to divert a part of the flood flow to fill his storage reservoirs. It is the duty of the State to permit all of these appropriations, but to so define both the time and amount that conflicts may be avoided.

O